AIRCRAFT FUEL SYSTEMS

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PREFACE

This book is written for the enlisted men of Naval Aviation. It is one of a series of books designed to give them the necessary information to perform their aviation duties.

A knowledge of aircraft fuel systems is of primary importance to Aviation Machinist's Mates and especially the Aviation Machinist's Mates (G). Other Emergency Service Ratings of the Aviation Machinist's group can also profit by an understanding of aircraft fuel systems.

Starting with an explanation of the function of the fuel system, this book contains information on tanks and tubing, fuel-line accessories and fuel pumps. Then it explains the principles of carburetion, and the kinds and use of gasoline. It describes the Stromberg float-type carburetor and the Stromberg injection carburetor. There is a section on the induction system, which includes discussion of intake manifolds and superchargers. The final chapter deals with Turbo-Jet fuel systems and fuels.

This NAVY TRAINING COURSE represents the joint endeavor of the Naval Air Technical Training Command, the U. S. Navy Training Publications Center, Memphis, Tennessee, and the Training Division of the Bureau of Naval Personnel.

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AIRCRAFT FUEL SYSTEMS

CHAPTER 1

TYPES OF FUEL SYSTEMS

COMBUSTION

You know what gasoline is, that is to say you know where we procure it and the primary use we have for it in Naval aviation. But have you ever seriously thought of the process whereby we use the latent energy in the gasoline to develop an energy which will do useful work?

First, we have the latent energy in the gasoline. Our problem is to convert this energy into mechanical energy. This is done through the process of igniting the fuel within the cylinder, thus converting the latent energy to heat energy which, in turn, causes the piston to be forced downward with force or mechanical energy.

Gasoline is not explosive. Rather a startling statement, but before you begin lining up your arguments, let's go a little further and explain that gasoline by itself will not explode. If a lighted match is plunged quickly into a pan of gasoline, the match will probably—remember that's PROBABLY—go out. If not, the surface might be set on fire, for gasoline is flammable.

Now, it is NOT recommended that you adopt the practice of dousing lighted matches in gasoline—stepping on them is much safer. If something did go wrong, you would probably never know what happened, and your next of kin might have difficulty in collecting your remains. Gasoline vaporizes at ordinary temperature, and there is hazard that the vapor will explode when mixed with the proper portion of air. Just such a mixture might exist above the surface of the gasoline at the instant that the lighted match contacted it, and then, Poof!—and oblivion.

Since gasoline is used as the fuel for cars, trucks, tanks, and aircraft, some means must be provided to vaporize the gasoline and to mix this vapor with air in such proportions that an explosion will occur in the engine cylinders when the mixture is ignited. So far, the term "explosion" has been used to describe the action in the engine cylinder at the instant of ignition, because it has been assumed that combustion occurred simultaneously in all portions of the charge. In an actual engine, however, combustion is not instantaneous, but starts at the point of ignition and spreads progressively to the remainder of the charge. Consequently, explosion is a misnomer. So let us use the term "combustion" hereafter when referring to the burning of the fuel in the engine cylinders.

THE ATOMIZER-CARBURETOR

All right, it is combustion, but how is the gasoline vaporized and mixed with the air in the correct proportions? Before

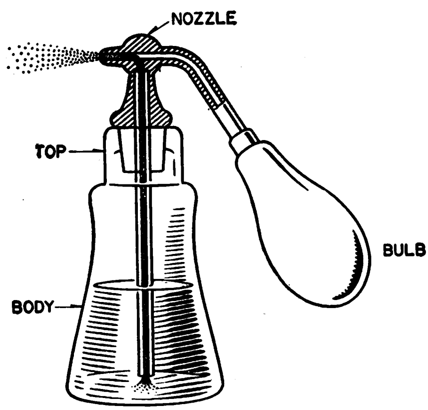

Figure 1.—Atomizer shows elementary carburetion principle.

going very far into this operation, take a look at a simple device known as an ATOMIZER.

The atomizer you see in figure 1 consists of three main parts; namely, the body containing the liquid, the top with its nozzle, and the bulb. The top section carries a tube,

the bottom of which is submerged in liquid. The upper end of this tube has a small opening. A second tube leads from the bulb to a point just above the opening in the tube. Now, what happens when the bulb is squeezed? The air in the bulb is forced through the tube and out of the nozzle at the top of the atomizer. As it passes the top of the tube, it produces a vacuum—or empty space—above the opening in the tube. The same thing happens in the tube that happens when you suck a coke through a straw. The empty space, or vacuum, above the tube causes the liquid to rise in the tube and pass through the top opening. The liquid inside the tube rises due to the difference between the pressure inside the tube and the pressure over the surface of the liquid. As the opening is very small, the liquid emerges in the form of a fine spray. This spray mixes with the air passing through the nozzle.

That is the elementary principle behind carburetion. More of this later, but right now it is well to find out how the gasoline reaches the carburetor.

CARBURETORS MUST BE FED

It is not news that gasoline is the breath of life to the airplane. It's understood also that the fuel must be carried in the airplane and conveyed to the engine. But there is much more to it than that. The gasoline must be fed to the engine in the proper proportion at all times, and must supply the engine with the much needed punch regardless of conditions. Just a split second hesitation of the engine to respond to the pilot's direction may mean the difference between life and death to the entire crew.

Your car runs on an even keel. Sure, you strike an occasional grade. But consider the airplane. It climbs at a sharp angle to the earth. It banks or rolls. It spins. It stands on its nose in a dive. It even turns upside down. Any of these maneuvers would "kill" the automobile engine. But to the airplane, they are simply a part of the daily "manual of arms." One minute the airplane is skimming the tree tops. A few minutes later it is a dot in the sky—where the atmosphere

is thinner and the temperature is lower. And the carburetor measures out the gas, accurately and constantly.

THE FUEL SYSTEM

Broadly speaking, the fuel system of an airplane consists of two general sections, the storage section and the pumping section. The storage section may consist of nothing more than a tank, provisions for filling the tank, and a shutoff valve. Larger systems, however, are not so simple, and usually consist of several tanks, selector valves, rapid refueling provisions, dump valves, and means for the transfer of fuel between the tanks and the carburetor during flight.

The practice of using several small tanks rather than a few larger ones has complicated the plumbing and layout somewhat, but it permits a more efficient use of the available fuel storage space.

The pumping section consists of the master fuel strainer, an auxiliary pump (operated either by hand or by an electric motor), a fuel-tank selector valve, engine-driven main pressure pump, pressure-relief valve, pressure gages, auxiliary strainers, and priming system. When more than one engine is used, some means of crossfeed between the engines is also required.

GRAVITY FEED

When a man bails out of an airplane, he immediately starts downward—or earthward. Why? Because a certain force—gravity—tends to draw to the earth all matter on or near its surface. In a gravity fuel system, as the name implies, the gasoline flows from a higher point to a lower point—or from the fuel tank to the carburetor—entirely by gravity.

The pressure system, on the other hand, employs a pump. The gravity system is simple and reliable, but, it won't do for modern war planes. Let's see why.

The actual pressure available from a gravity system is approximately 1 pound per square inch (abbreviated p. s. i.) for each 40 inches of head of fuel. The head, by the way, is the vertical distance from the surface of the liquid in the

tank to the point of discharge into the carburetor. When you realize that in some of the large airplanes, the required gasoline pressure runs as high as 15 p. s. i., or even more, you have one very good reason why the gravity system is impractical for such airplanes. The fuel tank would have to be located at a point $40 \times 15 = 600$ inches, or 50 feet, above the carburetor, which, you will admit, would require an unusually high airplane. Furthermore, the gravity system is not sufficiently reliable for use in modern war planes.

The gravity system is used in some light training planes, where the relative height of carburetor and fuel tank presents no serious problem, since the fuel pressure is comparatively low, and the tank, or tanks, are located in the wing.

There is no hand or wobble pump, no engine pump, no pressure gage, no bypass or relief valve in the gravity fuel system. It is composed of the tank and tubing that extends to the fuel shutoff cock, thence to the strainer and the carburetor. The primer may be connected into the line at any convenient place.

PRESSURE FEED FOR SINGLE ENGINE

You can obtain a good idea of the relation of the various parts of a pressure-feed fuel system from the diagram, figure 2, which illustrates a simple fuel system for a single-engine airplane.

Fuel is placed in the tank through the filler neck at the top, which is provided with a screw cap and a brass screen strainer to keep out foreign matter. At the bottom of the main tank are two outlets, both of which are fitted with screens. The main line outlet is located at a higher point in the tank than the reserve outlet in order that the ordinary gasoline supply may be taken from it, when the selector-cock control handle is turned to main. If this supply should fail, the cock may be turned to reserve, thus drawing gasoline from the tank through the reserve line for an additional half hour, or more, of flight. From the selector-cock the gasoline flows through the strainer and the hand pump of the A. E. L. Unit, and thence to the engine-driven pump.

Operation of the hand or electric pump will force the fuel through the main-pump housing by means of a bypass valve built into the housing.

When either the main pump or the auxiliary pump is operating, fuel passes through the adjustable relief valve that is built into each pump unit at the point where the fuel stream divides. Part of the fuel goes to the carburetor, or

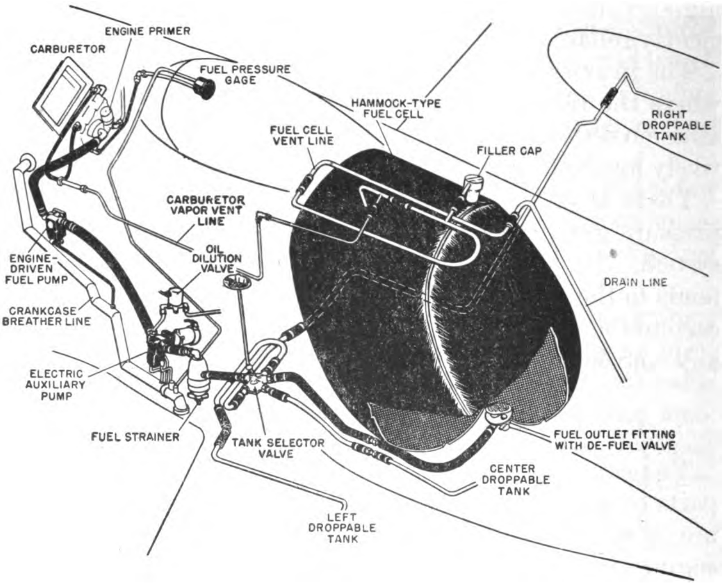

Figure 2.—Diagram of a single-engine fuel system.

carburetors, through the supply line according to the demands of the engine, and the excess escapes through the relief valve and returns to the inlet side of the pump. The fuel-pressure gage is connected to the carburetor in order to show the actual pressure of fuel delivered to the carburetor. The primer line is connected to the A. E. L. Unit and is provided with a shutoff valve in order to prevent any possibility of the fuel being drawn into intake manifold by way of the primer while the engine is running. The vent lines from the top of the tanks and the drain lines from the shaft of the fuel pump, the carburetor, or carburetors and tanks, lead clear of the fuselage to a safe point of discharge.

The exact pressure developed by the pump depends on the adjustment of the relief valve, and may be anywhere from 3 to 23 p. s. i., according to the type of carburetor. In general, a pressure of approximately 3 p. s. i. is used for a float-type carburetor, or mechanical fuel injector. A pressure of 16 to 23 pounds is used for a pressure-injection carburetor. In combat airplanes, the carburetor air pressure is appreciably higher than the normal atmospheric pressure, the increase being produced by an external supercharger.

There are variations in the set-up as illustrated in figure 2, such as the primer hook-up and the auxiliary tank installa-

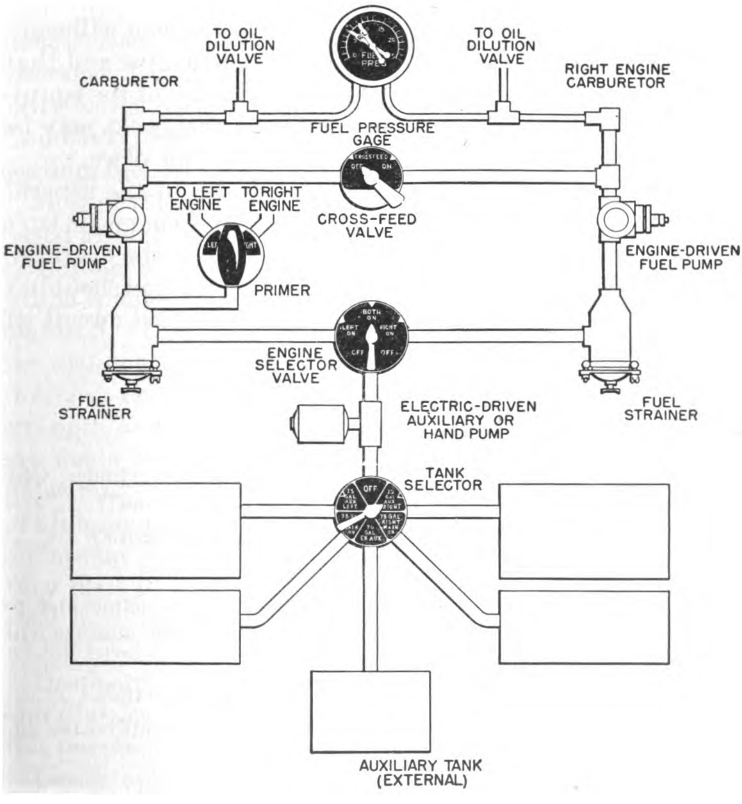

Figure 3.—Typical fuel system for two-engine airplane.

tion. In fact, each installation presents a slightly different problem.

PRESSURE FEED FOR TWIN ENGINES

When a plane has two engines, the fuel system is essentially that of two single engines, plus the arrangement for interconnecting the two systems by a suction or pressure cross-fuel line. With this circuit, a typical layout is illustrated in figure 3, you can operate both engines with a single engine-driven fuel pump, or with two or more pumps. Fuel can be supplied to one or both engines from either set of fuel tanks. By adding lines and units and following the same method of procedure, fuel-system circuits for airplanes having more than two engines are constructed. If you will compare the diagram of the system for a single engine and that for two engines, you will observe the similarity of the equipment in the two systems. Any number of fuel tanks may be employed, these being located at any convenient place.

By this time, you should have a good idea of the general layout of the fuel system of an airplane. Of course, it isn't quite as simple on the airplane as it appears in the diagram. But once the general plan is fixed in your mind, you shouldn't have any serious difficulty in tracing out the fuel circuit of any airplane.

QUIZ

1. Under what condition is gasoline vapor explosive?
2. In describing the burning of a charge in an engine cylinder, why is "combustion" a better term to use than "explosion"?
3. Why is the fuel-pressure gage connected to the carburetor?
4. What limits the pressure developed by the fuel pump?
5. Some means must be provided to -------- the gasoline and to mix it in the proper proportions with air so that the mixture will burn when it is ignited.
6. The master fuel strainer and selector valve are both in the --------.
7. The exact pressure generated by the fuel pump depends on the adjustment of the -----------.
8. The increase of carburetor pressure in combat airplanes is produced by an external ----------.

CHAPTER 2

TANKS AND TUBING

TANK CONSTRUCTION

Fuel tanks for training and utility aircraft are usually constructed of aluminum alloy, torch welded at the seams, and with the baffles riveted and then welded in place. Other metals, such as brass, copper, or terneplate have certain advantages, but their weight is so great that they are practically never used for gasoline tanks on modern airplanes. Combat types of aircraft are equipped with rubber-like, self-sealing, fuel cells for all internal fuel.

Most of the droppable auxiliary fuel tanks used on carrier based aircraft are now made of aluminum alloy. The main advantage of this material is high strength-to-weight ratio, which enables very light tanks to be manufactured from this material. Their durability is satisfactory and they are easy for maintenance crews to handle and install. Another metal that has been used with great success because of its high strength and stiffness is stainless steel. Fairly light tanks are made from this material. Steel is employed for droppable tanks because the cost of the material is less than that of aluminum. Because steel can be drawn much thinner than aluminum and still retain sufficient strength, its use adds very little to the weight of the airplane. Tanks made from steel have the edges joined by overlapping seam welding, which produces an absolutely tight joint.

Droppable tanks have also been made entirely of plywood and plastics. This material is not used much at present for this purpose, except in the case of collapsible tanks.

Large tanks may require internal plates, or baffles, located so as to break up the space into several small sections. These

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baffles provide increased rigidity of the tank, and prevent objectionable surging of the gasoline in flight. The baffles contain a large number of holes in order to reduce their weight, and also have openings at the bottom to permit complete drainage of the tank. In some cases, the shape of the tank makes the use of baffles unnecessary.

The fuel tank may be an integral part of the structure of the wing, hull, or float, or may be a separate removable tank, installed wherever space is available. The shape of the tank is variable, depending on the airplane for which it is built.

Externally mounted droppable tanks are of the conventional teardrop type, carefully streamlined to eliminate wind drag and to give better climbing ability. Droppable tanks are placed at any convenient point, such as the bomb bays, bomb racks, and wing tips. The tanks are shaped according to the space they are to occupy.

Teardrop external tanks are designed to fit under the plane wings or fuselage, and are attached in such a way that they can be dropped quickly in any emergency. The pilot can then switch to his regular fuel tank without interrupting the flow of gas to the engine. The use of the droppable tank increases the combat range of fighting airplanes. You will realize the importance of this, when you consider the great distances that airplanes must sometimes travel to reach objectives. Ordinarily, the regular fuel load is insufficient to make the round-trip journey and leave ample reserve for extended flying in combat.

Some tanks carry a separate compartment known as a reserve tank. Holes in the top of this tank permit it to be filled with gasoline when the main tank is filled, yet it will retain sufficient gasoline to permit the airplane to operate for a substantial length of time after the fuel is exhausted from the main tank.

One method of forming a reserve is to use a standpipe to which the main fuel line is connected. When the top of the standpipe is uncovered by the gasoline, the main flow will stop, but there will still be a reserve supply of gasoline equal in height to the length of the standpipe. A strainer, usually

of 10-mesh monel screen is provided at the top of the standpipe (or at the main outlet if no standpipe is used) as well as at the reserve-outlet fitting.

The usual method of forming a reserve fuel supply is to have a separate tank that is used for an emergency fuel supply.

A vacuum-relief valve is installed in the upper part of the tank to prevent the pressure within the tank from becoming less than that of the external atmosphere.

The filler necks of fuel tanks are installed so that an expansion space is automatically provided when the tank is serviced. A vent line from the top of the tank leads overhead, so as to reduce the danger of fire from fuel or vapors that may be discharged. It is an important part of your duties to see that this line is properly installed and free from any obstruction. The filler cap is located in the center of a handhole cover.

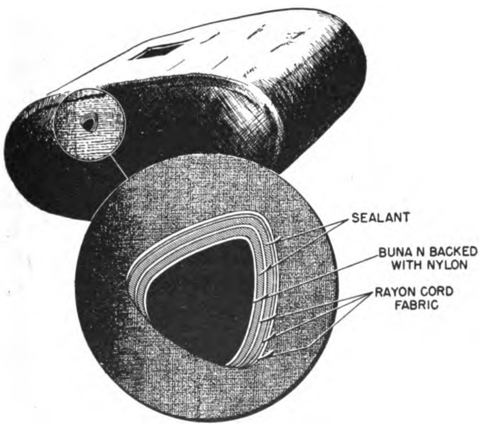


Figure 4.—A fuel cell.

Combat airplanes are equipped with self-sealing tanks. These tanks are effective against .50 caliber bullets and even single hits with a 20 mm. Self-sealing tanks are usually constructed of several piles of cord and synthetic rubber, as shown in figure 4.

A fuel-quantity gage extends from the top to the bottom of the tank and has a direct-lift float, the motion of which is

registered electrically on the gage. Other types of float mechanisms are employed, as explained elsewhere in this book.

INSTALLING TANKS

When installing some fuel tanks, it is necessary to use padding between the tank and the supports, or "tank bearer," and also between the tank and the retaining, or holddown, clamps or straps. This padding prevents chafing and damage to the tank. It is made of strips of felt from ⅛ to ¼ inch thick, and must be wide enough to cover the entire support. The felt should be impregnated with paraffin, oil, or asphaltic-base paint. Do not use padding of rawhide or composition material containing free alkalies or chlorides as it will cause corrosion of the aluminum. Use shellac to hold the felt in place on either the support or the tank.

In all cases be sure to anchor the tanks securely, as a slight shifting may cause a leak. Fasten the tanks so that vibration is reduced to a minimum, since vibration tends to crystalize the material of which the tank is made and produce cracks, particularly in aluminum and aluminum-alloy tanks.

When installing external auxiliary fuel tanks, it is necessary to check the shackles by which they are suspended for security, sway braces for proper tension, flexible fuel lines for security, cracks and chafing. Also, at this time, it will be necessary to check the fuel transfer pump to make sure it can transfer this gasoline to the main tank. Check to see that the main engine-driven fuel pump can transfer fuel directly to the carburetor from the auxiliary tank. Last of all, check the filler cap assembly.

MAINTENANCE OF TANKS

Metal gasoline tanks used on seaplanes and on other craft operating near salt water must be well protected on the outside by at least two coats of zinc-chromate primer. For this reason, when you are servicing a tank you should check the surface for exposed spots. If there are any such spots, give them the proper covering.

Metal tanks are always equipped with a removable container mounted in the sump or drain, in which dichromate crystals are held to prevent internal corrosion. These crystals must be renewed periodically.

When making repairs on a metal fuel tank, use the following procedure, so as to prevent damage to the tanks, and possible injury to personnel:

Drain the tank, disconnect all fittings, open vents, caps, etc.

Run a stream of hot water—temperature not over 150° F.—through the tank for one hour. Water must enter at the bottom of the tank, and flow out at the top. Make every effort to avoid a trapped air space within the tank. Then reverse the flow of water and run it through the tank from top to bottom for one hour. If hot water is not available, use cold water, but double the time—make it two hours—that the water flows from bottom to top.

Blow low-pressure compressed air through the tank for at least one hour—and as long as necessary to remove all odor of fuel.

Attach a red danger tag to the tank until the three foregoing operations have been completed. Then add a white inspection tag, bearing the date of purging and the signature of the inspector.

Circulate a stream of low-pressure air through the tank all the time while actual repair operations are being carried on.

Subject tanks that have contained fuel and have been in storage—even if previously purged—to the operations described here, before starting any repairs on them. Tanks that have been empty for months have been known to blow up with disastrous results, when an effort was made to repair them with a welding torch.

Prepare nonmetallic droppable fuel tanks for repairs in the same way as described for metallic tanks, except that the temperature of the water must be held to a maximum of 100° F., and the water must be circulated only from bottom to top, and for a duration of one-half hour only.

REPAIRING SELF-SEALING TANKS

The extent to which a self-sealing tank may be repaired effectively depends upon the seriousness of the damage, and the facilities available—to say nothing of the experience of the repairman. You can't handle one like the inner tube of a tire even though the actual patching process is quite similar. In the first place, you must have the proper equipment and material at hand. Even when thus equipped, you will find some tanks so badly damaged that they can't be repaired. When scrapping is necessary, save any flat areas that could be used in repairing other tanks less severely damaged. And be sure to save all fittings, as they may be needed to replace damaged ones in otherwise usable tanks. There may be plenty of material at hand at your shore station, but you may not find it so plentiful when repairs must be made at some distant point far from your base.

SYNTHETIC-RUBBER FUEL TANKS, both self-sealing and non-self-sealing, should be prepared for repair in the same manner as described for metal tanks, but the water temperature must be held to a maximum of 100° F.

When an airplane is brought into the shop for repairs, but no actual repairs of the fuel tanks are required, take the following steps to protect the tanks:

Drain all tanks completely through the drain valve at the lowest point in the system.

Fill the tanks slowly with CO_2 by placing the hose at the bottom of the tank. When CO_2 begins to escape from the drain, shut off the gas. Allow air to escape from the vent and filler openings. Since CO_2 is heavier than air, the air must be forced out at top.

NOTE.—The pressure of the CO_2 must not exceed 1.0 p. s. i. at any time during this procedure, as otherwise the tank may be ruptured. A hand valve and a 0.064 inch orifice in the CO_2 inlet line are recommended to keep the CO_2 pressure under control. Small tanks may require a 0.04 inch orifice.

This is IMPORTANT. Take readings on an explosion meter in the interior of the tank. When 100 percent in-

explosive readings are obtained throughout the tank, carry out the remaining steps.

Put the filler cap on the tank, but do not seal vent openings.

Attach a red danger tag to the tank until the first four operations are completed. Then add a white inspection tag, bearing the date of purging and the signature of the inspector.

Check the tanks every six days with the explosion meter. Refill with CO_2 if the meter indicates a necessity. Note the result, and mark on the inspection tag the result of the check.

The CO_2 purging WILL NOT INTERFERE WITH RECOMMISSIONING OF AIRPLANES. Fueling may be done without further attention to the tank.

NOTE.—Do not use the CO_2 purging procedure if tanks themselves require any inspection or work in the shop; or, if lines to tank must be broken for work in shop.

When making actual repairs on self-sealing tanks, refer to *BuAer Technical Orders* (T. O.), as repair methods and equipment are subject to change on short notice.

GENERAL NOTES ON SELF-SEALING TANK REPAIR

Let all repaired tanks dry for at least 24 hours at 100° F. (38° C.) before filling them with gasoline.

Wash cement out of the brushes with solvent immediately after using or the cement will become insoluble, and the brushes must be thrown away.

Do not work on self-sealing tanks in an enclosed room without proper ventilation. Wear a respirator if you are forced to work inside the tank. Solvent, cement, or fuel-vapor fumes may even be fatal. When practicable, air should be circulated through the tank to prevent high concentrations of vapor.

Another reason for preventing the accumulation of vapor is that this vapor is highly inflammable. Smoking or open flames must not be permitted where repairs are being made. To eliminate the danger of a spark that might be caused by

the scuffing of a shoe, wear shoes with full rubber soles, or sneakers. Don't let anyone else come near your job unless he is similarly equipped.

FUEL LINES AND FITTINGS

The fuel lines feed the gasoline to the engine. Should they cease functioning because of leaks or a failure of any of their vital parts, the engine will first sputter and cough—as though in protest—and then with a final gasp, will "die."

To lessen the danger of such failure, the fuel lines are installed in positions where there is a minimum possibility of damage. When the fuel lines are located in positions where they are likely to be injured by gun fire, they are formed of puncture-proof, or self-sealing hose.

In servicing an airplane, you can greatly lessen the likelihood of future trouble by observing the same rigid rules in reinstalling the fuel lines as were used in the original installation. Attention is drawn to some of the important rules.

Wrap self-sealing hose with tape where it passes through frames, bulkheads, fuselage skin, firewalls, etc.

When using clamps on metal tubing, do not make a metal-to-metal contact with the tube. Unless a special clamp with a rubber liner is used, place a couple of turns of friction tape or a piece of rubber around the tube where the clamp is applied.

Do not make inside bends in rigid tubing less than three times the outside diameter of the tubing. And make inside bends in self-sealing hose with a minimum radius of twelve times the inside diameter of the hose.

The diameter of the tubing must be uniform at all bends.

At a flexible connection, the tubing must be straight for a minimum distance of 3 inches before beginning a bend. At a solid connection the tube must be straight for a minimum of 1 inch before beginning a bend. To assist in tracing out the lines, each line is marked at both ends with a ½-inch band in accordance with BuAer Specifications. If the line is long, a similar mark is used at some inter-

mediate point. Fuel lines are marked to make it easy to identify them, and also to follow the line from one point to another, when necessary. The marking scheme will be indicated on the fuel-line map.

Fuel lines to the selector valve can be identified by using adhesive tape marked with typewritten numbers on the ends of the lines that are connected to the valve. After the tape is placed in position, coat it with clean shellac. Your job may be easier if you memorize the color schemes before checking the fuel system.

A diagram of the fuel system is sent out with each plane and placed in some convenient place such as the map case. This diagram may be used as a guide, but, when making major repairs, consult the *Erection and Maintenance Manual* for the specific model of airplane.

The rigid tubing used on modern airplanes is generally made of aluminum alloy. The size of the tubing is governed by the fuel-flow requirements of the engine. Connections between the tubing and the various units of the fuel system are made by pipe fittings, solderless flared-tube fittings, hose connections, or by a combination of these methods.

You will find that flexible joints of airplane tubing carry special clamps to which a short section of electric cable is connected. This process, known as bonding, is used to provide a complete electrical circuit throughout the entire pipe line. This prevents the building up of an electrical condition which would interfere with radio reception. BE SURE TO REPLACE THESE CABLES. If special clamps are not provided, bond the piping to some structure, such as the engine mount, with metal bonding clips and strips of flexible bonding braid. Before bonding to an anodized aluminum surface, scrape off the anodic film at the point of contact because the film has a very high electrical resistance.

Standard pipe fittings are shown in figure 5. The threaded portions on these fittings are tapered—¾ inch per foot—so that when any fitting is screwed tightly into another part, a leakproof connection is made. Permanent joint compounds are unnecessary and are generally barred. However,

approved lubricants that do not harden will be found beneficial in making pipe connections. These materials should function as lubricants. In no case, should you use them as sealing compounds for improperly installed fittings. Many units of the fuel system, such as tanks, fuel cocks, strainers, pumps, and carburetors, are provided with female pipe threads for the installation of various line fittings.

Threads of aluminum-alloy fittings have a tendency to seize and gall when the parts are screwed together. Therefore, when assembling such fittings, always use a lubricant. Apply the lubricant only to the external, or male, threads, so as to reduce the possibility of any of the lubricant entering the line. If regular thread lubricant is not at hand, make up a mixture of 25 percent lead soap and 75 percent mineral oil. Engine oil is a mineral oil and may be used.

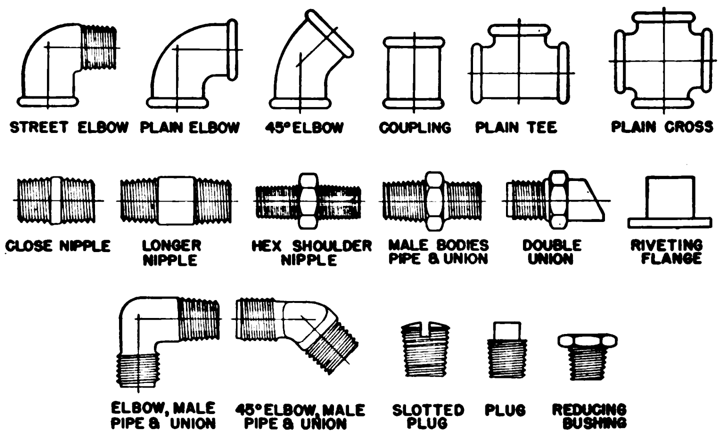


Figure 5.—Standard pipe fittings for airplane fuel systems.

When tightening fittings after lubricating the threads, be careful not to draw up the fitting nuts too tight. It is easy to place too much load on the threads without realizing it. Remember that you can't make incorrectly flared tubes seat properly by exerting excessive pressure on them. And if you place too much pressure on correctly flared tubes, you are liable to thin out the flare, and rupture or crack the tapered seat.

Flared-type couplings are used for connecting aluminum-alloy tubing. In the type that you see in figure 6 (*A*), the coupling consists of two pieces, one having an internal thread and the other an external thread. The internal member is slipped over the end of the tube. The end of the tube is flared, so as to fit the seat in the fitting. The external-threaded member is then screwed into the internal member, and its tapered end makes a gastight fit with the flared end of the tube.

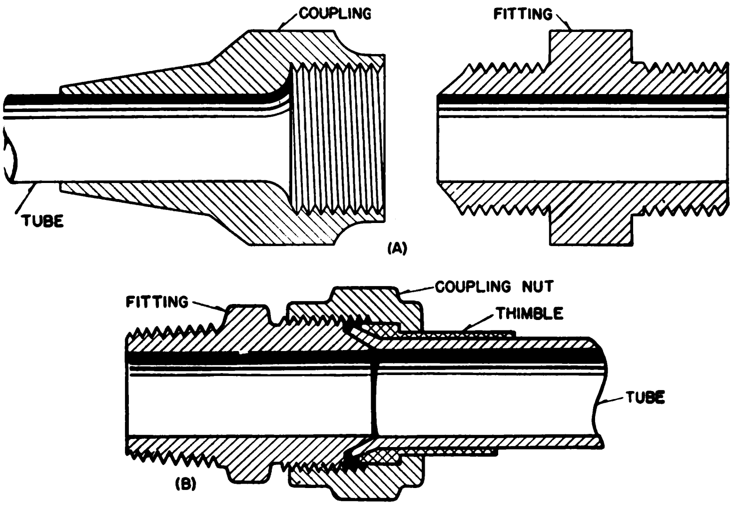


Figure 6.—Coupling for airplane fuel systems.

In the coupling shown in (*B*), a thimble, or flanged collar, is slipped on the tube after the nut, so that when the tube is flanged, and the coupling assembled as illustrated, the flange of the nut will bear against that on the thimble, and the thimble will press against the flange of the tube.

During disassembly of aluminum-alloy airplane tubing leave fittings with pipe threads in place wherever possible. Since pipe threads are tapered, taking the fittings apart frequently will result in enlargement of the inner threads to such an extent that a good connection can no longer be made.

In case you must do a coupling job on a new piece of tubing that has to be flared, do the flaring carefully, as the connection will leak unless the flared end fits accurately to its seat. A man handy with tools will be able to form a satisfactory flare with a bluntly tapered punch and a hammer. Many light blows produce a much better flare and are less likely to crack the flare than a small number of heavy blows. If a flaring tool is available, by all means use it. One of these tools, which is suitable for different sizes of tubing, is shown in figure 7.

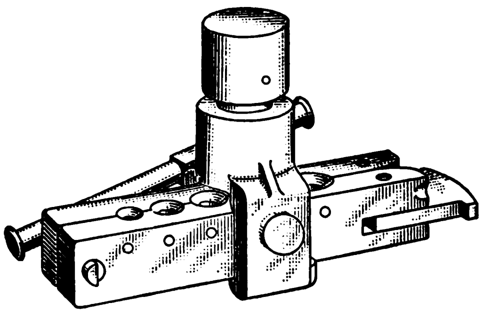


Figure 7.—Tube flanging tool.

The tube to be flared is clamped between the two blocks and the upper end of each tube hole is countersunk to conform to the exact shape of the desired flare on the tube. A punch or flaring pin is moved into position directly over the end of the tube in the countersunk hole, and is then struck with a hammer until the tube is properly flared. Unless the end of the tube is square and smooth—you should use a file for this purpose—you will probably get a one-sided or cracked flare. Make the flare slightly longer than the taper on the end of the clamping nut, and a little shorter than the tapered surface on the fitting, as is shown in figure 6 (*B*). Do not make the flare too long, however, as it will not be drawn down tight on its seat, and a poor joint will result.

Beading a tube may be done either by a beading tool or a beading machine according to the size of the tubing. An example of a beading tool as used for small tubing is shown in figure 8.

To make a bead—or raised collar—on the end of a tube by using a beading tool, insert the tube into the die through the opening formed by the parting of the die. Allow the tube to extend above the die a distance equal to about 1½ times the diameter of the tube. Place the assembly in a vise, and tighten up the vise sufficiently to hold the tube firmly in place. Insert the pilot of the beading tool into the tube, and strike the tool lightly with a hammer. The tube will bulge slightly just above the die at each blow of the hammer. Continue until the required bead is obtained.

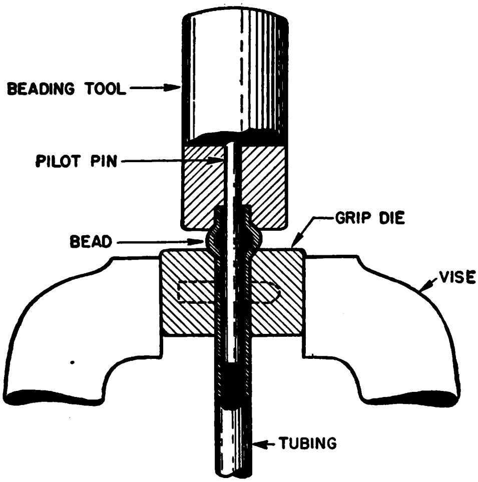


Figure 8.—Beading tool for small tubing.

Use a flexible connection at all points where there is a relative motion between two parts of the fuel line. This connection may be made by synthetic rubber hose or by a flexible metal tubing. The hose connection is common at the present time. You will see a joint of this type in figure 9. A synthetic rubber, which is not affected by gasoline and therefore requires no liner, is used for this purpose. The hose is held in position by means of a hose clamp at each end.

The vibration in an airplane tends to cause the flexible joints to become loose. For this reason, it is customary to have beads on the tube or fitting near the ends. In the illus-

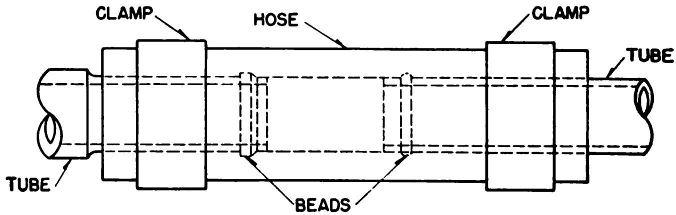


Figure 9.—Flexible hose connection.

tration, the bead on the fitting—the member to the left is formed by turning down the metal so as to leave a shoulder. The bead on the tube is formed by a tool such as shown in figure 8.

TUBE BENDING

If you have to bend tubing to make repairs on an airplane fuel line, the method to use will depend on the equipment that you have available. If you are at a shore station, for instance, and lucky enough to find a tube bender your job will be much easier. If you're not so lucky, you will have to do the best you can with what you have. Before bending a tube, bend a piece of soft wire or rod to the shape that the tube is to have. Use this for a pattern when doing the bending. After the tube is bent, handle it carefully, so as not to change its shape. Remember, also that the last few inches near each end of the tube must be straight, to permit the fittings to be slid back when the joint is broken.

Keep the ends of tubing that are to be joined by any sort of fittings absolutely in line with each other. Otherwise, the threads of the coupling become crossed and either make assembly impossible, or form a joint that is not safe.

When cutting tubing, be sure that the ends are straight. If possible, use a regular tube cutter. But, if you must use a file, take care to make the end of the tube square with the sides. If you can find a tubing vise, use it. File the end of the tube until the file runs flat across the face of the vise. Then remove all burrs, as, otherwise you will probably have a leaky joint or split tube. Remove inside burrs with a

scraper or a pocket knife, and outside burrs with a file. Take care not to round off the ends of the tube too much.

FUEL PRESSURE-CONTROL SYSTEM

Navy high-performance airplanes are equipped with a device that maintains definite predetermined pressure in the fuel tank above that of the atmosphere in which the plane is operating. This pressure eliminates fuel-system trouble that formerly occurred at high altitudes. A system so equipped is known as a fuel-tank pressure-control system.

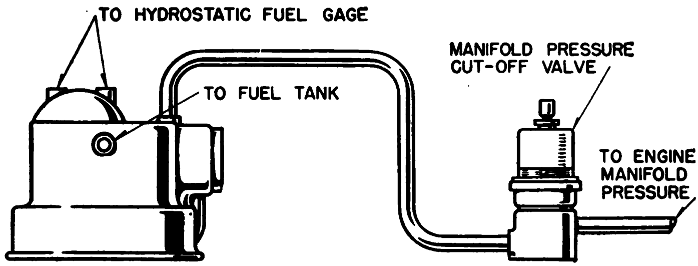


Figure 10.—Diagrammatic layout of pressure-control system.

The system operates in connection with the fuel pump, and the tank or tanks are under pressure only when the airplane is operating at altitudes at which fuel-system trouble normally would occur. Consequently, the system is designed to apply pressure to the tanks automatically when the airplane rises above approximately 12,000 feet. Below this altitude, the normal vent system is in operation, and there is no pressure imposed on the tanks.

In a system previously used on some Navy airplanes, the tanks were under pressure at all times, and this made more of a fire hazard in case of a crash. The system now used presents no greater hazard than that of an airplane without it.

The pressure-control system, figure 10, consists primarily of two major units, the main regulator unit and the manifold pressure cutoff valve. The manifold pressure is the pressure existing in the manifold or the part of the system connecting

the carburetor to the engine. The main regulator (control) unit can be located at any convenient point in the airplane, provided it does not allow spillage of gasoline. In most cases, the unit may be installed in the same location as any other fuel-tank vent junction.

The pressure-control system consists essentially of a shutoff valve that is operated by altitude, a pressure-regulator valve, and another altitude-operated valve that opens or closes the fuel-tank vent system. There are also two safety valves held to their seats by springs. One valve opens away from the tank and keeps the pressure in the tank not over ½ pound per square inch (1 inch of mercury) greater than specified, in case of failure of the pressure-regulating valve. The other valve opens toward the tank, and hence will open when the atmospheric pressure is greater than the pressure in the tank. This prevents the fuel tank from being subjected to a vacuum during rapid descent of the airplane, even in case the automatic valves fail to function.

All the valves mentioned are automatically operated and should require no attention. However, in case the pressure-control system fails to function properly, a hand control is provided for emergency use. The system is made inoperative by turning the control in the cockpit to the off position. The hand shutoff control normally should be left on (forward). Exceptions—When the tank is punctured in combat, or when the tank pressure is not required to maintain satisfactory engine operation at the actual combat altitude, or as an additional safeguard in event of a forced landing under adverse conditions.

The use of the fuel-tank pressure-control system has produced some definite advantages in the operation of the fuel system. With a pressure of 3½ p. s. i. (usually referred to as 7 inches of mercury), it has been possible to maintain a constant fuel pressure at the carburetor in a rapid climb to altitudes considerably in excess of 30,000 feet. The ratio of vapor to liquid is considerably reduced, causing a minimum interference with the carburetor metering characteristics. Also, the closing of the vent system from the tank pre-

vents the loss of the more volatile parts of the fuel by way of the vents and reduces the apparent fuel consumption during high-altitude cruising.

Because of the operational advantages stated, it should be desirable to place the pressure cutoff control in the off position only when:

The tank, or tanks, are emptied of fuel.

The pressure in the tank exceeds that specified for the system by more than 2 inches of mercury (1 p. s. i.).

The pressure in the tank falls to more than 1 inch of mercury (½ p. s. i.) below atmospheric pressure.

A failure occurs in any of the lines or valves.

The system starts imposing pressure on the tank below 10,000 feet.

Any emergency occurs not specifically covered in the first five items.

FUEL BOOSTER PUMPS

Some airplanes are equipped with a fuel booster pump instead of a fuel-tank pressure-control system. This system not only serves to prevent fuel-system failure resulting from vapor-lock at high altitude but also operates as an emergency fuel pump in high-pressure systems in the event of engine-pump failure. The booster pump further operates as a primer and pressure pump when starting the engine and can be used to transfer fuel between tanks at any altitude.

A fuel booster pump consists of a centrifugal type pump built into the frame of an electric motor. This pump is connected to the engine-driven fuel pump, the inlet being through a throat or casing attached to the pump body. The pump body houses the impeller blade and the sealing parts.

The principle of operation of the booster pump will be made clear to you by looking at the diagram in figure 11. In this particular installation, the pump is mounted on the fuel tank, but it may be attached to a detached sump if more convenient. When the pump is operating, fuel is drawn into the impeller housing. As it comes in contact with the revolving impeller, the fuel attains a high velocity, with a conse-

quent reduction in pressure. This results in the formation of vapor, which is thrown out by the impeller blades, and escapes to the top of the tank in the form of bubbles, as illustrated. The fuel is discharged under pressure into the fuel line. It is important that no obstructions exist that would prevent the passage of the vapor to the top of the tank. Otherwise, the pump will not operate.

When the booster pump is not operating, fuel is drawn through it by the engine-driven fuel pump.

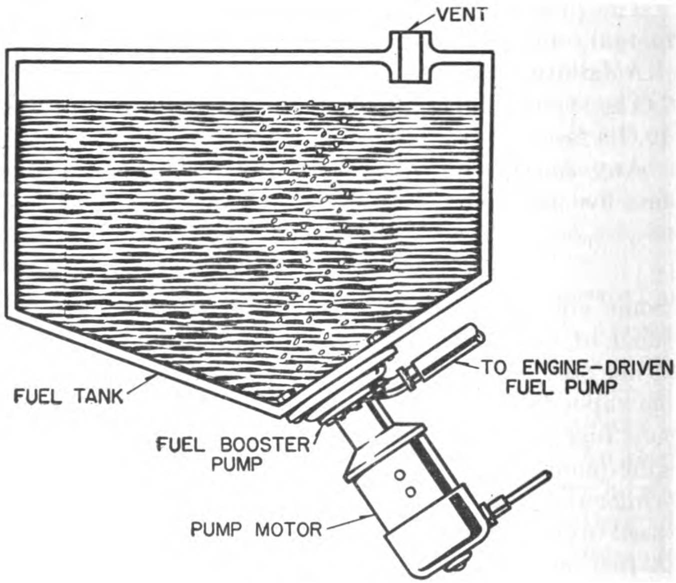


Figure 11.—Operation of fuel booster pump.

Pump bearings are of the sealed-grease type, and the pump requires no lubrication in service. Servicing, other than exterior cleaning, replacement of seal parts, and the replacement of brushes, should not be done at any station except major air stations where complete overhauling facilities and replacement parts are available.

VAPOR-RETURN SYSTEM

In some airplanes, a vapor-return line from the carburetor is attached to the top of the main tank. Under normal engine

operating conditions, approximately 5 to 8 gallons of fuel are returned to the main tank in one hour of engine operation.

When the engine is operating with a full main tank and with an additional quantity of fuel in the wing tanks or the droppable tanks, always be sure that sufficient fuel is used from the main tank first, to insure space for the fuel that is returned from the carburetor. Otherwise, the return fuel will cause the tank to overflow through the vent lines. By starting and warming up the engine with the selector-valve control in the reserve position, a sufficient amount of gasoline will be removed from the main tank to take care of the vapor-return system. After takeoff, first use the fuel carried in the droppable tanks or wing tanks. Use that in the main tank last.

REFUELING

The refueling of an airplane is something more than just filling the tanks with gasoline. In the first place, you should not put implicit faith in the fuel gages. They sometimes do get out of order. When servicing is done regularly on a number of identical airplanes, you should check each tank with a measuring stick marked off, or calibrated, for the particular type of tank to be filled. The measuring stick may be calibrated in gallons or be marked off so as to read quarter full, half full, and three-quarters full. Sometimes the gage will indicate correctly but not show the true contents of the tank because of bulging of the self-sealing unit.

Fuel should never be placed in an airplane tank except on definite instructions from an authorized party, such as the flight officer. It is important that the person in actual charge of the refueling should thoroughly understand the exact amounts and kinds of gasoline that are placed in the tanks. A record should be made of each refueling.

Never take anything for granted about the important operation of refueling. Always act on definite instructions. A fuel of the proper octane rating must be used according to the design of the engine, and a notation of this rating should be made somewhere near the engine or fuel tanks.

It hardly seems necessary to warn against smoking any-

where near gasoline. Carlessness sometimes becomes a habit in this respect, and if smoking is indulged in around the highly volatile fuel used in aircraft engines, disaster is likely to strike the smoker and his mates, as well as destroy any airplane or airplanes in the vicinity. Aviation gasoline should be "handled with gloves" (rubber gloves) at all times and precautions must be taken to prevent spilling it, especially on yourself. The chemical makeup is such that the gasoline causes painful and serious irritation when it touches the skin. Remove clothes wet by gasoline as soon as possible, and wash any parts of the body touched by the gasoline with soap and water. Also avoid breathing the gasoline fumes, as they may cause illness or even be fatal.

Never use, or allow to be used, dirty equipment in handling aviation fuel. Even though the fuel passes through several fine strainers between the tank and the carburetor, a small particle of foreign matter from a dirty receptacle might get through, and cause serious trouble when the airplane is in flight. If funnels are used, rinse them in gasoline and see that they are thoroughly clean before using them. When a hose is used, see that its nozzle is clean and preferably rinsed off just before using. It may have been dropped on the ground since the last filling.

Never let the weight of the funnel and the gasoline in it rest on the filler neck or pipe, as this places undue strain on the neck. Take the same precaution with a filler hose. The nozzle used with a hose is usually of heavy brass and is of considerable length. If it is allowed to extend into the filler neck of the tank and rest there by its own weight, it may exert enough leverage on the neck to bend or break the neck loose at the tank joint.

The friction of gasoline passing through the filling hose and nozzle induces static electricity. You are familiar with it. It is the same thing that causes the spark to jump from your finger to a piece of metal after you have scuffed your feet across a rug.

This static electricity can be highly dangerous around an airplane fuel system, for it can cause a spark that may quite

easily ignite the gasoline. For this reason, it is highly important that you ground the funnel or hose whenever you are preparing to refuel an aircraft, and keep it grounded until the operation is completed. These parts are grounded when they make a good metal-to-metal contact with the tank. This is best accomplished by soldering one end of a large copper wire to the funnel or hose nozzle and providing the other end of the wire with a clip. Before opening the gas tank cap, attach the clip firmly to the filler neck of the tank, so that any charge of static electricity developed during the filling will pass through the wire and into the tank metal and be conducted to the common ground. Then it will not cause a spark by jumping the gap between the parts as the funnel or hose is withdrawn.

Observe the same precaution when drawing fuel from an underground tank into a tank truck, or directly into the airplane tanks. Do not refuel an airplane during a thunderstorm or when one is "brewing" if it can possibly be avoided, as the air is charged with static electricity at such times. Wait until the storm has entirely passed over and the danger from this source no longer exists. Even after the storm has passed, ground the entire airplane as a safety measure before refueling. This grounding is particularly necessary for metal airplanes. It is usually done by attaching a large copper cable firmly to the metal of the airplane and attaching the other end solidly to a metal prong that can be forced well into the earth. The tank truck should also be grounded when refueling the airplane.

The original method of preventing water from entering the fuel system with the gasoline was to strain all fuel through chamois skin and then funnel it into the tanks. Chamois skin possesses the ability to permit the passage of gasoline but prevent the passage of heavier substances including water. While this method positively prevents water from entering the fuel tank with the gasoline, it is too slow a process to be adapted to modern airplane operation.

The practice now employed is to strain the fuel carefully through a chamois or felt strainer or a strainer with an

exceedingly fine mesh screen into the container from which the airplane tank is to be filled. The container, which may be a tank truck, or even a number of cans, should be cleaned periodically and carefully. Since many makes of screen strainers will not remove water from gasoline, always test this type by passing saturated gasoline through it into a can or pail before adapting it for actual use in refueling an airplane. Also, be sure that any chamois or felt used for straining gasoline is not water soaked because a water-soaked chamois will pass water.

All closed metal containers are subject to condensation of water on the inside. This is the result of heat and cold reaching the container alternately. The placing of storage tanks beneath the ground reduces this tendency to a certain extent by keeping the tank always at a comparatively low temperature. Even this practice does not altogether prevent condensation because the earth itself changes temperatures with the seasons. Almost all fuel trucks and underground storage tanks are equipped with some type of water trap or separator which filters the gasoline before it leaves the container. Be sure to drain and clean out this separator at regular intervals.

If necessary to store gasoline for any length of time above ground in 5- or 10-gallon tanks, pour the gasoline from the cans smoothly with as little agitation of the gasoline as possible. Do not empty the cans entirely but leave in the bottom of the cans any accumulation of water and rust. Strain carefully, preferably through a chamois skin, gasoline used from such containers.

GENERAL REFUELING RULES

All squadrons have their own specific rules and regulations regarding the refueling and oiling of equipment. The following practices will be found in effect generally throughout the Navy.

When an airplane comes in for service, measure the fuel in each tank with a clean measuring stick and write down

the exact amount in each tank. Printed forms are generally available for this purpose.

Examine the tank filler caps and their retainer chains, and, if found defective, repair or replace. If a filler cap should come loose in the air, it might very easily be blown back or fall where it will cause serious damage. Furthermore, if the air is rough or bumpy, gasoline may splash out over the airplane creating a serious fire hazard. Examine the tank vents carefully to see if they are open and clean. Unless the filling is to be done immediately, replace the filler caps after checking. Never trust your memory to "do it later," but do it now.

When working around an airplane, don't step except where a step is provided. If you must do so, place your weight as close to a structural member as possible.

Never drag a gasoline hose over the airplane structure. Always lift it into position, providing a pad of some kind between the hose and the airplane.

Do not permit a tank to overflow when you are filling it. Measure the amount of gasoline in the tank first, so you will know the exact quantity required.

Replace the tank caps and lock them with the safety device, if such is provided, and again make sure that the retainer chain is in good condition.

Remove all rags, funnels, etc., used in the refueling. If the measuring stick belongs with the airplane, wipe it off and put it back in the place where you found it. Finally, wipe from the airplane all traces of fuel or oil.

If the airplane has been flown for several hours since last servicing, remove the fuel strainers and clean them out. Also drain the water trap. This should be done daily. If, upon examination, you find an excessive accumulation of water, rust, dirt, small metal or rubber particles, or sediment, report the matter to your superior at once. Several crashes have occurred because of contaminated fuel. Lives depend on clean fuel.

After replacing the strainers and the water trap and properly securing them by the safety device provided, test them

for leakage by turning on the fuel cock and building up pressure with the wobble or electrically operated pump. Never exceed the pressure specified for that particular system.

When the refueling operation has been completed, it is advisable to drain the sumps of the fuel tanks by means of the drain cocks. If pipe plugs are provided instead of cocks, it is better to drain the sumps before refueling.

If it is necessary to refuel an airplane in the rain, take full precautions to prevent any rain water from entering the tank.

Make certain that the fuel is of the proper octane rating. Never refuel an airplane with a fuel of lower octane rating than that specified by the engine manufacturer. The only objection to operating on fuels of higher octane rating than that for which the engine is designed is the danger of corrosion and slightly increased wear if the fuel contains more tetraethyl lead, the antiknock ingredient added to the fuel.

On airplanes carrying several tanks, and all tanks are not to be filled, the order of filling is specified in the airplane operation book. Always fill the tanks in the prescribed order. If not, takeoff may be attempted on an empty, or almost empty, tank. Also the center of gravity—or stability—of the airplane is affected by the order of filling the tanks and the use of fuel from them.

Do not have open fires in the vicinity of the airplane during refueling, and, when refueling at night, never use an ordinary flashlight. When an ordinary flashlight is turned on or off a small electric spark is produced sufficient to ignite a gasoline-air mixture.

QUIZ

1. Mention three rules you should follow, when repairing self-sealing tanks, to avoid being affected by the fumes.
2. How far before the beginning of a bend must tubing be straight for a flexible connection? A solid connection?
3. (a) What name is given to the process by which a complete electrical circuit is provided throughout the pipe line of the aircraft fuel system?
   (b) What is the purpose of this process?

4. What can you use for a thread lubricant when a regular lubricant is not available?
5. In what position should the selector-valve control be when you start an aircraft engine?
6. (a) What is the purpose of the vapor-dilution system in aircraft fuel tanks?
   (b) By what general means is its purpose accomplished?
7. Why should an airplane's fuel tanks always be filled in the order specified in the airplane operation book?
8. Combat types of aircraft are equipped with -------------------- for all internal fuel.
9. Most of the droppable auxiliary fuel tanks used on carrier based aircraft are now made of --------------------.
10. Self-sealing tanks are usually constructed of ------------------.
11. Metal tanks are always equipped with a removable container mounted in the sump or drain, in which are ------------------ to prevent internal corrosion.
12. Do not make bends in rigid tubing less than -------------------- times the outside diameter of the tubing.
13. The rigid tubing used on modern airplanes is generally made of --------------------.
14. A fuel booster pump consists of a -------------------- type pump built into the frame of an electric motor.
15. Due to the possibility of static electricity around aircraft fuel systems, it is highly important that you -------------------- the funnel or hose whenever you are preparing to refuel the aircraft.
16. The water trap should be drained --------------------.
    a. at the 60-hour check.
    b. daily.
    c. at the 120-hour check.
    d. weekly.

CHAPTER 3

FUEL-LINE ACCESSORIES

FUEL STRAINER

Sentinels are stationed at strategic positions in the fuel system of an airplane to prevent dirt and other alien enemies from sneaking into the carburetor with the fuel, and sabotaging the "works." Some of the sentinels—or strainers—are placed on the outlets from the fuel tanks. These are of comparatively coarse mesh and prevent only the larger particles from entering the fuel lines. Other strainers are placed in the line itself and in the carburetor inlet. These are fine-mesh strainers.

A strainer provided with a screen of fine mesh is located at the lowest point in the fuel system. A strainer of this type is shown in a diagrammatic section in figure 12. Its function is an important one, for it not only prevents foreign matter from entering the carburetor, but, because of its low position, it traps any small amount of water that is present in the system. More than one strainer unit is used in some multiple-tank installations.

In the particular strainer unit illustrated, the fuel enters at the side, passes through the screen, and leaves at the top. While the fuel is passing through the strainer body, all dirt or sediment settles to the bottom where it can be drained by opening the drain cock. The drain cock is usually connected to a pipe so that the strainer will drain outboard. Drain the strainer after each flight, and remove and clean the screen when checking the engine. Use a gasoline spray and compressed air, if available, when cleaning the screen.

Some form of priming system is necessary in an airplane fuel system to provide the additional fuel required to start the engine. The airplane engine is no different in this respect than an automobile engine. You probably have vivid memories of many a battle with the old bus on raw winter mornings, or after it had been standing out in the cold all day. Use the choke too sparingly, and the engine would backfire and stall. Prime her too much, and she would flood and stand there and defy you. Gas-engine design has made considerable progress during the past several years, but, so

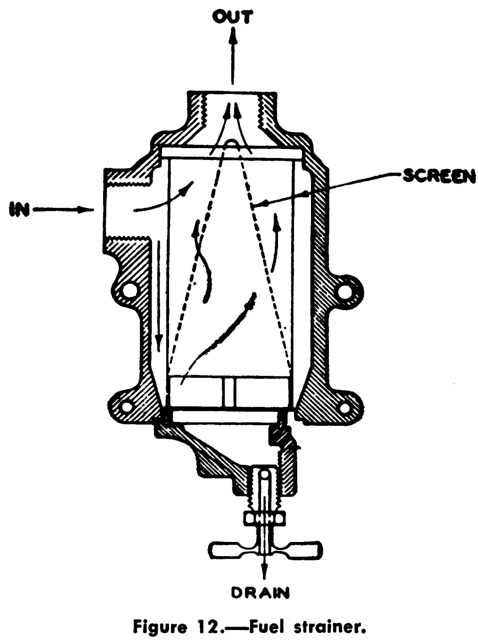


Figure 12.—Fuel strainer.

far, there hasn't been any way figured out whereby the age-old priming nuisance could be eliminated.

Different practices are followed in injecting the priming fuel. In some cases, the fuel is discharged into the intake. In others, it is injected at the carburetor, or the supercharger.

The priming system draws fuel from a point in the fuel

system under pressure and directs it either through a distributor to the various cylinders or, in the case of an internally geared supercharged engine, discharges the fuel into the supercharger diffuser section through a jet located on the carburetor or in the diffuser section.

Some priming systems utilize a hand operated wobble pump for pressure in conjunction with a hand operated primer plunger which directs the raw fuel to the engine. It operates by pumping pressure with the hand wobble pump and at the same time slowly drawing the primer plunger out until it is full of fuel, then rapidly forcing the plunger in, forcing the fuel in a semiatomized state into the distributor

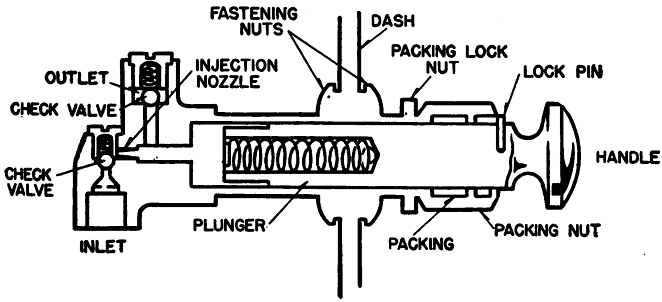


Figure 13.—Hand-operated priming pump.

which directs it to the cylinders. This priming system is not in general use, because placing the plunger and all its attendant fuel lines in the pilot's compartment is a fire hazard.

The system in general use today employs the electric auxiliary fuel pump to supply the necessary fuel pressure and the use of a remote controlled electric solenoid primer valve. The solenoid valve is usually located on, or near, the carburetor and is wired to a priming switch in the cockpit. When the switch is engaged, the solenoid actuated valve opens and allows fuel, under auxiliary pump pressure, to enter the priming system. The valve is returned to the closed position by means of a spring, after disengaging the switch. The amount of fuel injected into the priming system depends upon the length of time the switch in the cockpit

is held engaged or by the number of times the switch is "flicked" on and off. The Pilot's Handbook for the particular model of aircraft will give the average procedure for priming the aircraft, but only experience will enable you to correctly prime the engine since the starting characteristics of each plane will differ.

FUEL-PRESSURE GAGE

A fuel-pressure gage is provided on an airplane to indicate the difference betwen the fuel pressure and the air pressure at the points where the fuel and air lines enter the carburetor. Gages of the type used with externally supercharged engines have two connections—marked fuel and air—on the back of the case. The air vent is connected to the air-pressure chamber of the supercharger. Airplanes with internally supercharged engines have the air connection of the gage open to the air pressure in the cockpit, since the pressure is substantially the same as the air pressure at the carburetor intake. Only the fuel connection to the gage need be made in this case.

In order to dampen—or lessen—pressure impulses that cause pointer variation, a restricted fitting with a small hole—usually the size of a No. 60 drill—is used to connect the fuel-pressure line at the carburetor. This small opening also prevents excess leakage of fuel in the event of failure of the fuel-pressure line. The correct fuel pressure depends upon the type of carburetor. The gage registers the correct pressure at the carburetor only when the gage is installed at the same level as the carburetor. If the gage is located much above the carburetor, the reading will be lower than the carburetor pressure. When the line is partially or entirely filled with gasoline, the column of fuel in the gage line exerts a downward pressure which cancels a portion of the pressure at the carburetor. Thus, if there is a 3-pound pressure at the carburetor, but enough fuel in the gage line to exert a downward pressure of 1 pound per square inch, the net reading at the cockpit gage will be only 2 pounds.

Even though you may never have occasion to open one of

these fuel-pressure gages, it is a lot of satisfaction to know what "makes it tick." For this reason diagrams showing front and side views with the gage casing cut away are given in figure 14.

The fuel-pressure line from the carburetor is connected to the rear case of the gage by means of a pipe-fitting of the type illustrated. The pressure is then transmitted through a passage to the inside of a curved tube, known as a Bourdon tube. The opposite end of the curved tube is closed, and the natural tendency of a curved tube supported only at one end is to straighten out when pressure is applied to the open end.

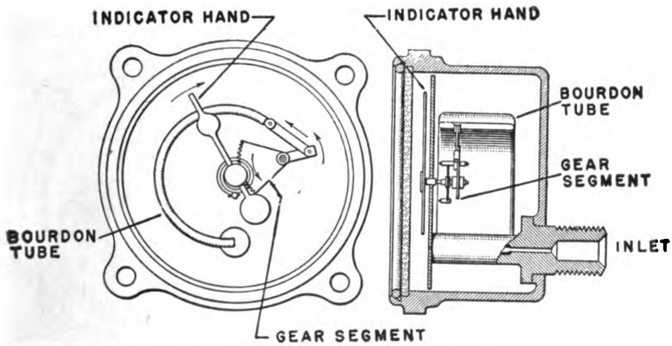


Figure 14.—Principle of fuel-pressure gage.

If you don't believe it, fold up a sheet of paper into a flat tube. Paste one end shut, roll the tube into a coil, and blow into the other end. The tube will straighten. When the pressure is removed from the metal tube, the springiness of the material causes the tube to return to its original shape.

In the fuel-pressure gage the tube is connected by links to a gear segment, which is pivoted so as to be free to rotate. As the Bourdon tube straightens out, the gear segment is caused to rotate in a counterclockwise direction, as indicated. The segment is meshed with a small gear on the shaft that carries the indicator hand. As the segment rotates, the shaft carrying the indicator hand rotates in the opposite, or clockwise direction, as indicated by the arrow at the end of the hand.

The fuel-pressure gage is calibrated—that is, graduation are marked on the dial—in whatever units are desired.

Fuel-pressure gages require no special maintenance. If the accuracy of the reading is in doubt, test the gage against a standard gage of known accuracy. When the pressure gage line is also used as a primer supply line, air leakage

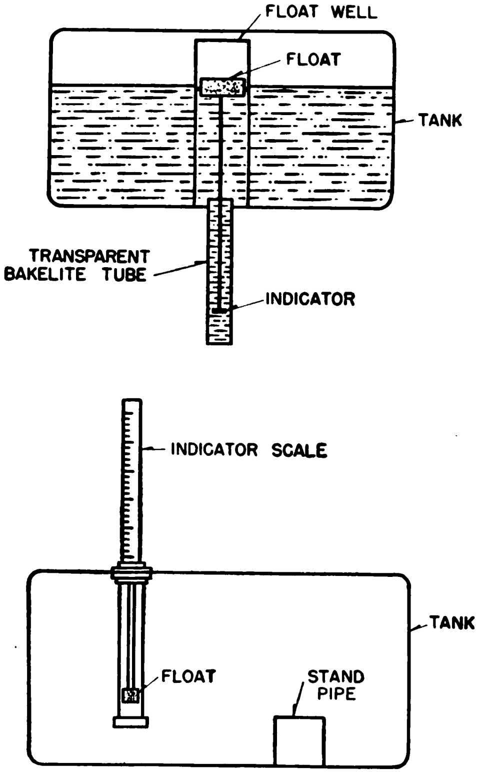


Figure 15.—Simple types of fuel-level gage.

at the primer may cause the fuel to drain from the line. In such a case, the fuel pump or fuel system may appear to be at fault, whereas the pressure at the carburetor may remain constant, and the pressure gage may be in error. Air bubbles in the line can be prevented by filling the line with fuel when installing.

FUEL-QUANTITY GAGE

Many gages for indicating the contents of fuel tanks—usually known as fuel-quantity gages—are of the float type but differ in the methods employed in transmitting the indication to the float instrument panel. Three types are in common use, namely, direct mechanical, hydraulic, and electrical.

In its most simple form, the fuel gage consists of a float connected to a rod that indicates the number of gallons in the fuel tank directly on a scale. Gages of this type are illustrated in the diagrams, figure 15. The direct-reading gage is usually visible through a window in the fuselage, so that it may be watched while filling the tank.

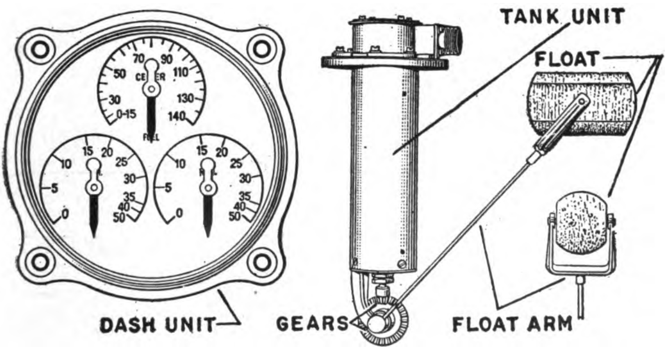


Figure 16.—Electric-resistance type of fuel gage.

The electric fuel gage is made in different types. In the electric-resistance type, a float in the fuel tank is attached to a lever and moves a contactor over a calibrated resistance unit. The unit is connected in series with a battery and a sensitive voltmeter—an instrument for indicating the voltage, or pressure, of the electric current. The parts are connected in series when the current flows through them one after another. The value of the effective resistance in the circuit changes according to the level of the fuel in the tank which deflects the voltmeter according to the resistance. The voltmeter is graduated to read in gallons or in fractions of a tank, as 1/4, 1/2, 3/4, and full.

A system providing remote fuel-level indication of several tanks with the gages grouped in one instrument, is shown in figure 16. The indicator consists of three or more indicating elements, three being shown in the illustration, each operated by a separate liquid-level transmitter, one of which is located in each tank. The indicator dials are graduated in gallons, and show continuous fuel-level indication of all of the tanks to which the gage is connected. Each individual tank design requires special application and calibration of the transmitters and indicators.

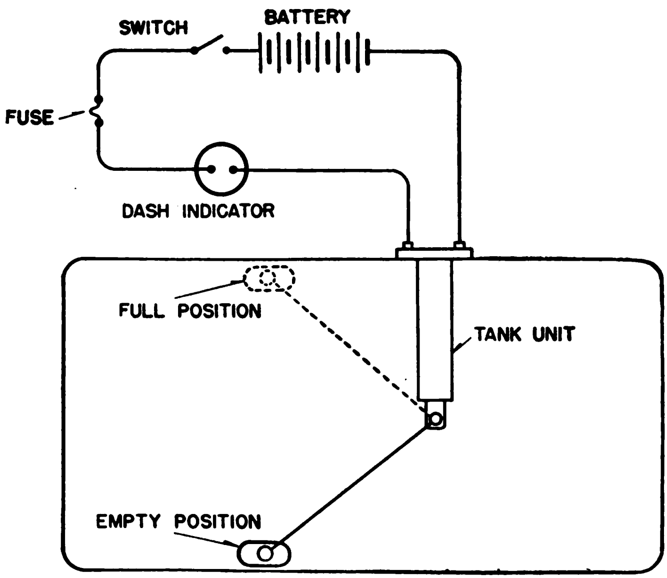


Figure 17.—Circuit diagram of electric fuel quantity gage.

The transmitter is actuated by a float-and-arm arrangement controlled by the level of the fuel in the tank. The float is constructed of cork, and is given a special treatment to withstand immersion in gasoline. A stainless-steel lever is attached to a pivot at the center of the float. When the float rises or falls as a result of change in the fuel level, the motion is transmitted through the lever and a pair of gears to a U-shaped magnet inside the aluminum tube, causing the

magnet to rotate in an aluminum cup which forms a gastight seal. Inside the cup, a short bar magnet attached to the shaft of the transmitter alines itself with the poles of the U-magnet, causing the transmitter shaft to rotate when the float moves. This movement causes a change in voltage, which in turn, causes the rotor of a permanent magnet on the indicator shaft to assume the definite position of the transmitter arm.

The circuit of the gage is shown diagrammatically in figure 17. Check the full and empty readings periodically. You can do this while the tank is full; or, if it is not desirable to fill the tank, you can hold up the float by hand. However, checking by raising the float by hand will not indicate trouble in the float itself, which may have lost some of its buoyancy.

CAPACITOR TYPE FUEL QUANTITY GAGE

The capacitor type fuel quantity gage is an electronic system for measuring fuel in aircraft in pounds. The operation of most systems requires a 28 volt d-c. power supply. The system consists principally of a tank unit for each tank, power units, and an indicator.

The tank unit is designed to be mounted inside a fuel tank with a coaxial cable connecting it to the bridge circuit of the capacitor system. The tank unit consists of two aluminum alloy tubes, the smaller assembled concentrically within the larger tube. Space between the tubes is approximately 1/32 of an inch except at the bottom where the inner tube is tapered to drain off water droplets which might be formed by condensation. A drilled hole in the top cap vents the air, while a hole in the bottom cap permits fuel to enter the unit.

The two tubes function as a condenser and work on the principle that the dielectric of the insulating medium between condenser plates in an electric circuit varies the electric capacity of the condenser. This combination of two metallic plates in the cell unit is so situated that when the cell is full, only fuel is between the tubes. As fuel is used, an increasing proportion of air replaces it, until there is only

air between the tubes. The proportion of fuel or air between the tubes of the cell unit affects the electrical capacity of the unit (because the dielectric constant of fuel and air differs) so that the capacity may be said to be a function of the fuel level at the particular location of the cell unit. The changes in the electrical capacity of the cell unit are measured by a capacitance measuring unit, or power unit, in which an electronic circuit measures the value of the electric capacity of the cell unit in terms of small direct current. These small direct currents are in turn fed to a ratiometer type indicator.

MANIFOLD-PRESSURE GAGES

In an airplane equipped with an engine that is not supercharged, the available horsepower of the engine steadily decreases as the airplane gains altitude. The reason for this is that the pressure of the atmosphere becomes less as the altitude increases. Finally, at a relatively low altitude, the power available is reduced to such an extent that the airplane can climb no higher.

Ordinarily atmospheric pressure is about 15 p. s. i., and will support a column of mercury about 30 inches in height. Estimated roughly, atmospheric pressure drops off at the rate of about 1 inch of mercury for each 1,000 feet. So at 10,000 feet, for instance, atmospheric pressure is only about 20 inches of mercury or about 10 p. s. i. To overcome this difficulty, a supercharger is employed to pump air into the engine. Some limit must be placed on the amount of pressure that can safely be imposed by the supercharger, or damage to the engine will result. Because of this, and in order that the pilot may be kept informed of what is taking place, a manifold-pressure gage is installed in the airplane.

Specific uses of the manifold gage are:

To prevent over supercharging when operating engines at low altitudes.

Indicate loss of power when flying at high altitudes.

Indicate safe power output of engines.

Serve as a guide when adjusting automatic controls for external-type superchargers.

A manifold-pressure gage consists of a tightly sealed case which is connected to the intake manifold of the engine by means of an airtight tube so that the pressure in the manifold is always maintained in the case. The dial of one type of such gage will be seen in figure 18. Inside the case is an aneroid and a suitable mechanism for transmitting deflections to the indicator pointer. You may not be familiar with the operating principle of the aneroid but the simple diagram shown in figure 19 should make its operation clear. The air pressure is measured by the action of the atmosphere on a closed collapsible chamber, or diaphragm capsule. Air has previously been exhausted from this chamber, so that the

Figure 18.—Dial of a manifold-pressure gage.

outside air tends to collapse it. The inner side is fastened to the frame of the instrument, and the other side carries a post with a pin through the end. A curved steel spring that is fastened to the outer end of an upper post passes under the pin in the lower post. The outer end of the spring is connected by a link to one arm of a bell-crank. The other arm of the bell-crank is attached to a chain that is wound on a wheel; the wheel is fixed to a spindle that carries the gage pointer.

The tendency of the diaphragm to collapse is opposed by the action of a steel spring. As the airplane rises, the air

pressure within the casing decreases, and, when the airplane drops to lower altitude, the air pressure increases. As the pressure decreases, the diaphragm expands, and, when it increases, the diaphragm contracts. This deflection on the part of the diaphragm, and, consequently, on the end of the curved spring is transmitted through a lever and connecting mechanism to the pointer of the gage.

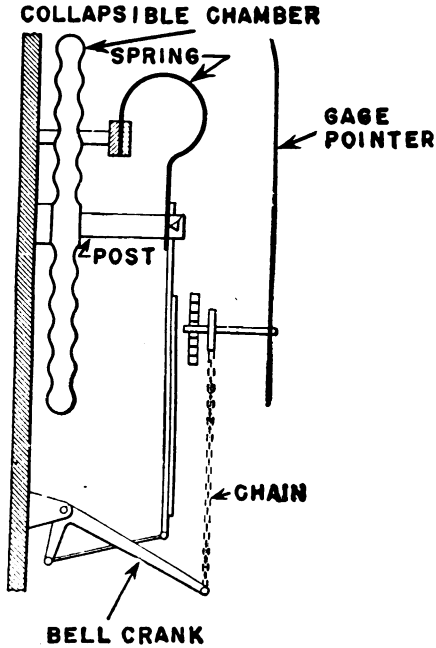


Figure 19.—Principle of aneroid barometer.

The Navy manifold-pressure gage is calibrated in inches of mercury. It could just as well be graduated in pounds per square inch, or any other unit of pressure, but inches of mercury is the standard. For many years the normal range of these instruments was 10 to 15 inches of mercury. The AN standard instrument now has a range of 10 to 75 inches of mercury. The higher range is necessary because of the more powerful superchargers with high-performance engines.

You will remember that atmospheric pressure at sea level

is equivalent to about 30 inches of mercury. Hence, when the engine is not running, the manifold-pressure gage will equal that of the atmosphere and show a reading of about 30.

Because the manifold-pressure gage indicates the same pressure as the barometer when the engine is not operating, the gage may be checked for correct reading in that range by comparing it with the reading of some other barometric instrument. The airplane altimeter is an accurate barometric pressure-measuring instrument and is handy for comparison. To make the check, first set the pointer hands on the altimeter at zero and tap the instrument panel gently. With the pointer hands at zero, the barometric scale on the altimeter will show the local barometric pressure in inches of mercury. Compare this reading with that on the manifold-pressure gage. The latter reading should not differ from that on the altimeter by more than .4 (four-tenths) inch of mercury.

After the engine is started, open the drain cock in the pressure-gage line for about 30 seconds while the engine is idling. This will clear the line and the gage of any condensate that may have collected there. When the drain cock is closed and the engine is idling, the pointer should move to the left since the absolute pressure in the engine manifold will be low, that is, 10 to 15 inches of mercury. As the throttle is advanced and the engine increases in speed, the pointer should move to the right, or in a clockwise direction.

The pointer should always have a slow and steady movement and be free of any oscillations regardless of how quickly the engine speed is increased or decreased. Any variation in the operation other than this is an indication of either of two defects; namely, a leak in the gage line or case, or improper damping—or restricting—in the line. The restriction is provided at the pressure inlet fitting to prevent rapid fluctuations of the pressure within the case.

Check the instrument for leaks in the case by first disconnecting the gage line at the pressure end, and then applying pressure until the line is closed tight. A leak will be indicated if the pointer returns to atmospheric pressure.

Check the restrictor adjustment by suddenly releasing the pressure when the gage indicates 50 inches of mercury. The pointer should drop to 32 inches of mercury in not less than 1 second or more than 2 seconds.

FUEL-SELECTOR VALVES

Fuel-selector valves have a number of uses in airplane fuel systems. They may perform one or more of the following functions:

- Select the tanks from which fuel is to be taken for the engines.
- Select the engine or engines to which the fuel is to go.
- Select the tank, for tank-to-tank transfer.
- For use in refueling.

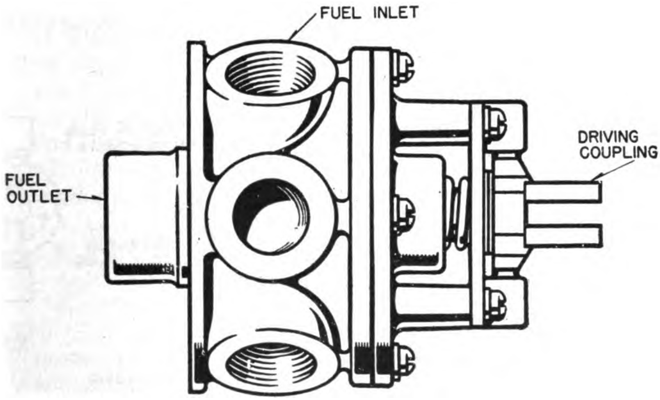
In figure 20, view (*A*), you will see an outside view of a commonly used type of selector valve. The central rotating section, or plug, of the valve is connected through a flexible joint and a rod to the dash unit, an example of which is shown in view (*B*). Fuel enters the valve either through a port at the side or at the center of the rear of the housing, according to the design of the instrument. When the selector lever on the dash is in the off position, the inlet of the valve is not connected to any outlet, and no gasoline flows from the tanks. This position is shown in view (*B*).

The simple diagrams in figure 21 will show you the principle on which fuel-selector valves operate. When the dash lever is in the off position, the opening in the central plug is not registering with any fuel line. This position is shown in view (*A*). When the dash lever is moved to a tank position, the center valve turns so as to connect the inlet port with an outlet line and fuel flows from the tank selected. This is illustrated in view (*B*), in which the center tank is supplying gasoline and the two side tanks are shut off.

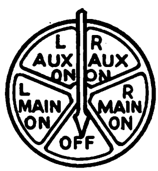
For many years the cork-plug fuel valve was in general use, but it is being replaced in Navy airplanes by a valve that uses a monel-metal plug and synthetic-rubber seats. The objection to the cork-plug valve is that when it stands idle the cork has a tendency to bulge into the valve ports. This bulge

makes the valve hard to turn and sometimes results in pieces of cork being sheared off. If lubricant is placed on the cork to make it turn easier, the lubricant is soon washed off by the gasoline. The major overall dimensions of the monel-metal selector valves are the cork-faced type.

Engine failure can be caused by the improper positioning of the selector valve. When shifting the valve from one tank to another, watch the pressure gage. If the pressure drops, check the setting of the valve so as to insure correct posi-



(A)



(B)

Figure 20.—Fuel-selector valve.

tioning. If, before shifting to another tank, the fuel pressure decreases or is lost because of draining the tank, the pressure should return to normal after the shift is made. If it does not, operate the emergency fuel pump momentarily to purge the system of any air that may have been drawn into

it. When using the emergency pump, watch the fuel-pressure gage so as not to exceed the proper pressure at the carburetor.

When the selector valve is not centered correctly, either the flow of fuel is restricted, or a second inlet port in addition to the one intended is at least partially open. If the second port leads to an empty tank or a reserve standpipe above the fuel level, air enters the system and causes engine failure. Even if there is fuel at the second port, there still may exist the unsatisfactory condition of using fuel from a different tank than the one desired as well as the possibility of fuel drainage from one tank to another.

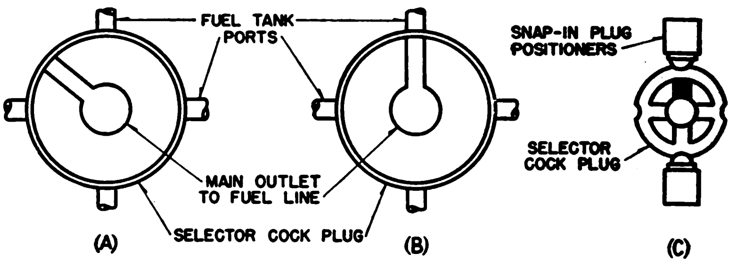


Figure 21.—Principle of operation of fuel-selector valve.

Backlash may develop in the selector-valve control linkage, and the fact that the lever on the cockpit control unit is set in the center of the correct dial sector does not necessarily mean that the valve plug is in the correct position. Be sure that the valve "clicks" audibly when you move the lever to the desired position, as this removes guesswork from the operation. Spring-actuated position-finding lugs are provided in the valves, and these snap into detent notches in the valve body in the various dial positions with a definite, audible click. See figure 21 (*C*).

QUIZ

1. What two temperatures determine the amount of priming necessary to start an engine?
2. Mention three points where priming fuel may be injected into the aircraft engine.
3. What are the two most frequent sources of trouble in the hand-operated priming pump?
4. Why will a fuel-pressure reading be lower than the actual pressure at the carburetor if the gage is located very far above the carburetor?
5. What is a simple way to check the accuracy of—
   (a) a fuel-pressure gage?
   (b) a manifold-pressure gage?
6. How can you be sure that the fuel-selector cock is in the desired position?
7. When cleaning the screen in a strainer, use a ____________________ and compressed air if available.
8. Airplanes with internally supercharged engines have the air connection of the gage ____________________.
   a. open to air pressure in the cockpit.
   b. sealed.
   c. connected to the supercharger.
   d. connected to the carburetor.
9. The ____________________ gage indicates the pressure delivered to the carburetor by the supercharger.
10. When using the emergency pump, watch the fuel-pressure gage so as ____________________.

CHAPTER 4

FUEL PUMPS

ENGINE-DRIVEN TYPE

The purpose of the engine-driven fuel pump is to deliver a continuous supply of fuel at the proper pressure and at all times during operation of the airplane engine. The type of pump in universal use at the present time is the eccentric, or offset, sliding-vane type.

The principle of operation of this type of pump will be made clear to you by looking at figure 22. Fuel enters the pump at the opening marked in, where it is picked up by vanes, which are caused to rotate within a housing by the rotor shaft. The vanes, which vary in number in different makes of fuel pumps, have a sliding fit in the rotor shaft, so that at all times during the rotation of the shaft, both ends of the vanes are in contact with the housing.

The fuel is carried around to the opposite side, and since there is no other place that it can go, it is forced out of the port marked out, and thence through a pipe to the carburetor.

Since the pump is symmetrical about a horizontal axis, it will pump in either direction with equal efficiency. Most pumps of this type are plainly marked to indicate the discharge port for either direction of rotation.

To maintain a constant pressure at the carburetor, a relief valve must be provided on the pressure side of the fuel pump in order to bypass fuel either back to the inlet side of the pump or to the gasoline storage tanks. Earlier airplanes carried separate relief valves, but the practice now is to have the relief valve built into the fuel pump.

Fuel pumps must also have a bypass valve which will allow fuel to pass through the pump when the pump is not run-

ning. This is necessary so that the auxiliary pump can send fuel through it to the carburetor when the main fuel pump is inoperative, as, for instance, before the engine starts running, or in case of fuel-pump failure. The bypass valve also serves as a safety valve in case the engine should rotate backward because of backfiring.

In earlier-type pumps, the relief-valve spring was located in a metal bellows, or sylphon, but in more recent designs, the bronze sylphon is replaced by a diaphragm made of synthetic rubber reinforced with fabric. The diaphragm provides greater flexibility, and is not as readily subject to failure because of fatigue resulting from valve pulsation.

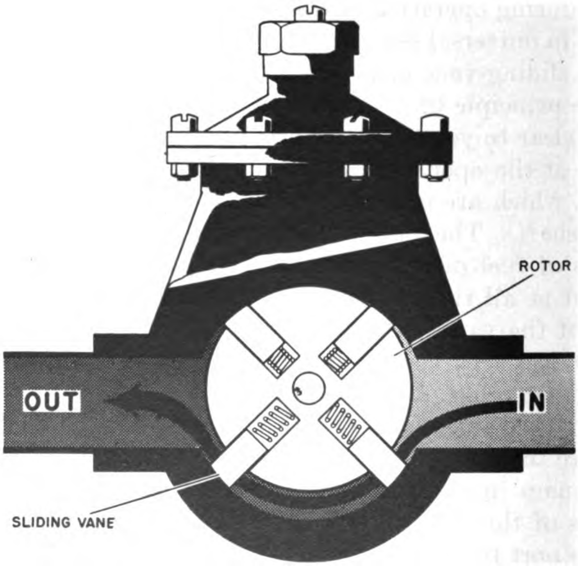


Figure 22.—Operation of engine-driven fuel pump.

It is a fact that metals and other materials "become tired" after having been exposed to a repetition of a stress, and will break down, just as in the case of overworked human bodies.

The action of the relief valve and the bypass valve can probably be best made clear to you by means of a simple diagram such as shown in figure 23. In order to furnish a

constant supply of fuel to the carburetor under all conditions, the fuel pump is designed to deliver much more fuel at any speed than the engine actually requires. Therefore, a spring-loaded (meaning that the valve is held to its seat by a coiled spring) relief valve is placed in parallel—like a siding on the railroad—with the pump, in order to release the excess fuel to the intake side of the pump.

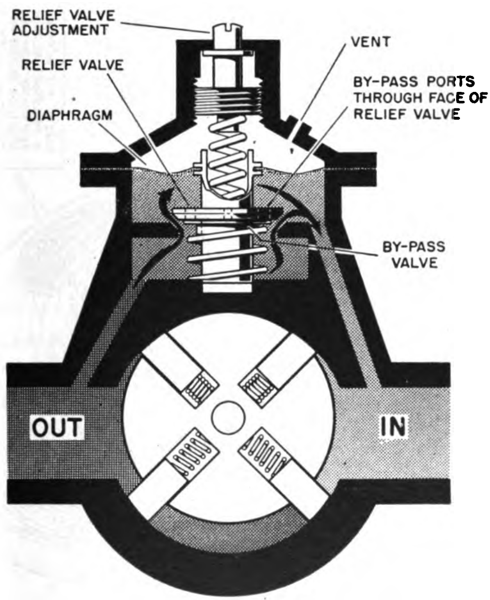


Figure 23.—Fuel pump showing relief valve and bypass valve.

By looking at the illustration, you will see that the fuel enters at the in port and passes out of the out port, as already described. If the pressure at the discharge side of the pump exceeds that for which the relief valve is set, the valve is raised off its seat against the pressure of its closing spring. Fuel then passes through the opening thus made and back to the inlet side of the pump, the course of the fuel through the valve being indicated by the arrows.

The bypass valves are held closed by the pressure of the fuel on the discharge side of the pump when the pump is

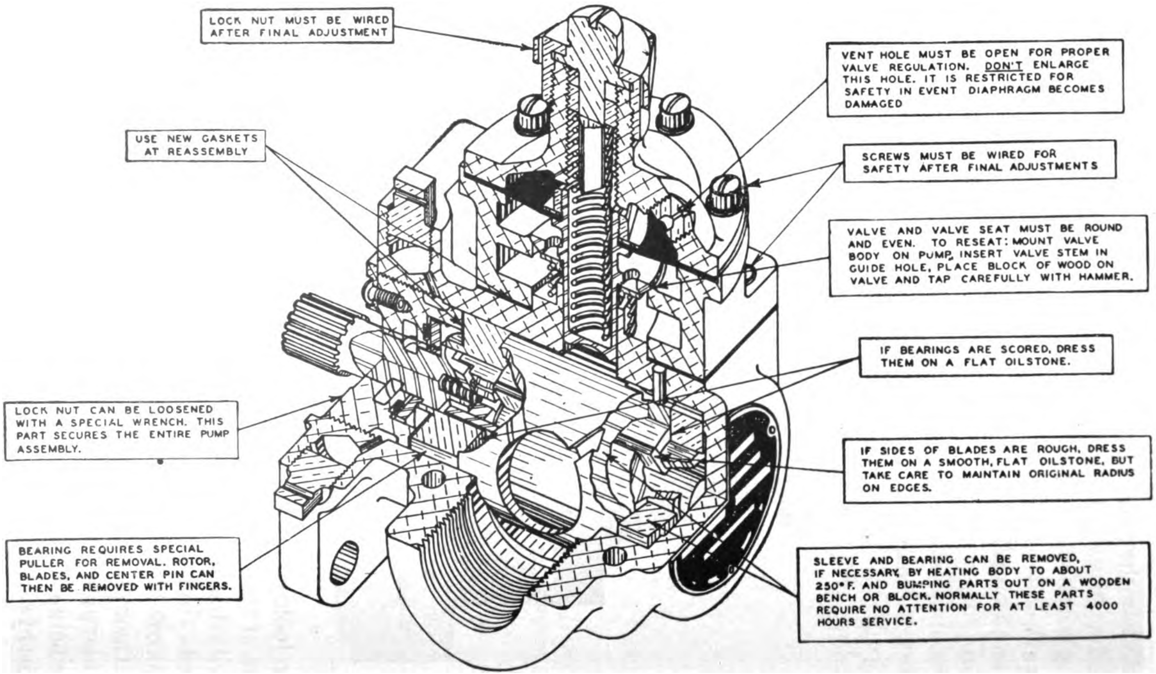


Figure 24.—Cutaway view of engine-driven fuel pump.

running. When the engine-driven pump is inoperative, and fuel is forced through the pump housing by the auxiliary, or priming pump, the fuel enters the pump at the usual inlet. It is prevented from passing directly across to the outlet by the stationary vanes, and goes through the bypass valves to the discharge side of the pump, and thence to the carburetor.

With the operating principle just outlined you should have little difficulty in understanding the construction of the actual fuel pump. Figure 24 shows certain sections cut away so that you may see the interior.

The diaphragm, or bellows, incorporated in the relief valve is essential for two important reasons. First, it permits the space above the valve to be vented, and thus aids in maintaining constant discharge pressure regardless of variations on the inlet side of the pump. Second, by connecting the vent to the carburetor scoop or the engine supercharger, a constant pressure difference between the fuel and carburetor-scoop (manifold) pressure is maintained. For proper altitude compensation, the vent must be kept open. If it should become clogged by ice or dirt, while the airplane is flying at higher altitudes, the pump discharge will decrease while the plane is descending. If the vent should become clogged during ascent, the pump discharge pressure will increase as the altitude is increased. The vent opening is made small so that the loss of pump suction will be lessened in the event of damage to the diaphragm or sylphon unit. Do not enlarge the vent opening. Inspect the opening and its protecting screen at each engine check. Probably the easiest way to check the vent opening is to insert the shank end of a No. 80 drill into it.

There are different makes of fuel pumps in common use, but the general principle is similar in each case; the chief distinction being in the number and type of vanes used. One pump, for instance, employs solid vanes while the others have split vanes.

Main fuel pumps are mounted directly on the engine and are driven by a square, tongue, or splined-drive coupling. All pumps do not rotate in the same direction, and you

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should check the proper direction of rotation before installing the pump. Also, see that there is end clearance at the drive shaft, as otherwise the shaft seal will be ineffective.

MAINTENANCE

Fuel pumps require very little maintenance between overhauls which should usually be done at the same time as the engine overhaul. At 20-hour intervals, you should inspect the vent opening into the relief-valve upper body or cover plug as already described. Inspect also for leaks, proper operation, and security of pump mounting.

Find out how the pump is lubricated. Some pumps must be lubricated periodically, and in others the drive shaft and coupling are lubricated by the engine oiling system. Do not apply grease through the drain openings.

In case of faulty operation of the relief valve or bypass valve, remove the valve assembly and inspect the valve seat, valve, and valve-stem guide for the presence of foreign matter. Wash the parts thoroughly and check the valve stem and guide for easy action. See that no dirt is lodged on the facing or seat of the bypass valve, and that the air-vent line and vented pipe plug at the supercharger air connection are free of obstructions.

To adjust the pump-discharge pressure, it is necessary to change the compression on the relief-valve spring. To do this on some pumps you will have to loosen the locknut at the top of the pump. In others, the valve-cap nut must be removed in order to get at the adjusting screw. Insert a screwdriver into the slot of the adjusting screw and turn the screw in to increase the compression of the relief-valve spring and raise the pump-discharge pressure, and turn the screw out to lower the compression and decrease the discharge pressure.

After the adjustment is completed, tighten the locknut or replace the cap, and lock the nut or cap in place by wire.

Fuel-pump overhaul should be undertaken only at properly equipped overhaul stations where complete facilities for repair and testing are available. As there is little likelihood of your finding such facilities, the best thing to do, if pos-

sible, is to replace the pump with a good one, and then send the old one back for repair. In case the replacement pump happens to be a new one, observe the following instructions.

Remove the shipping plugs from the parts, drain out the excess oil, wash with clean gasoline or cleaning fluid, and test for freedom of rotation. The pump should turn smoothly when rotated by hand, although it may be fairly stiff because of the shaft seal surfaces being dry. A small key or adjustable pliers may be used in turning the driveshaft, but never apply any undue force. If there is a catch when the shaft is rotated in this way, it indicates the presence of dirt. Rewash the interior with clean gasoline.

After the pump is installed, connect the intake and discharge lines. See that the pump port and line fitting threads are in good condition for gasoline-tight joints. If the pump is mounted directly on the engine, use flexible connections at the pump ports to insure against failure of the tubes because of vibration. Make all connections carefully, and support all tubing in accordance with BuAer requirements.

Install a ¼-inch (outside diameter) drain line from the lowest hole in the pump, and direct the open end of the tube into the slipstream. This line is provided to carry away any fuel that works out of the seal and must be kept free of traps that would interfere with the drainage. Make the connection to the supercharger or carburetor air scoop with a ¼-inch tube. If no such connection is necessary, plug the vent hole with a vented plug.

AUXILIARY PUMP

The auxiliary fuel pump is very similar in construction to the main engine driven fuel pump. The main difference is that it derives its driving force from an electric motor instead of being dependent on the engine gearing to drive it. This means it can be operated independent of the engine and makes it very useful for priming the engine for starting.

This type of pump may be used for obtaining pressure to prime the engine for starting, boosting the fuel pressure at altitude or as an emergency standby pump for takeoff and

landings, or may even be used as a fuel transfer pump if so located.

When used as a pressure pump for starting, it is used in conjunction with a priming solenoid which opens a path for the fluid.

When used as a booster pump it is hooked in series with the main engine driven fuel pump and delivers fuel to the main pump under pressure boosting the pressure and helping eliminate any possibility of a vapor lock.

When used as an emergency standby, it will have the same hookup as the booster pump, and, in case of failure of the main pump, it will serve the same function as the main pump by using the valves and fuel lines of the main engine driven fuel pump.

As a fuel transfer pump, it may be located either in the line loading to the auxiliary tank, or it may be submerged in the tank with the transfer line leading from it.

The maintenance of the electric-driven auxiliary pump is very simple and consists mainly of checking the electrical leads and motor which drive it.

FUEL-SYSTEM MAINTENANCE

You should now have a clear picture in mind of the entire fuel system and be in a position to be able to follow to the best advantage the following maintenance instructions each time the airplane is brought in for an engine check.

Check the condition of the fuel tanks. Look for cracks, buckling, dents, distortion, and for signs of leaks. Check the tank mounting support. There should be no slack in straps or evidence of strain or play that will be aggravated by engine vibration.

Note the condition of the padding.

Check the fuel lines. Look for leaks, and inspect sharp bends for cracks. See that clips and other mountings are secure. Examine the tubing for wear resulting from vibration.

Remove the fuel strainers and drain out the water. If you find an excessive accumulation of water, rust, dirt, small

metal or rubber particles, or an undue amount of sediment, report it at once to your superior. After replacing the strainers and water trap, turn on the fuel pump and build up pressure in the tanks with the auxiliary pump, being careful not to exceed the pressure specified for the system.

Check the condition of the strainer screen. Renew it if you think it necessary.

Check fuel gages. If the gages are of the float type, note whether the hands move smoothly without sticking when filling the tanks, and whether the quantities indicated agree closely with those known to be in the tank.

Check the fuel-control valves for free operation, backlash, and accuracy of pointer indication. If excessive backlash is noted check the operating linkage for worn universal joints, loose pins, broken drive lugs, etc.

Check the hand-priming pump, if used, and see whether it operates freely and develops the required pressure. Check both electrically-driven and engine-driven pumps for security of mounting and the proper adjustment of the relief valve. Inspect the pump periodically and lubricate when necessary.

Check the engine primer or primers for free operation and for signs of leakage at the packing.

QUIZ

1. What opening is provided to allow fuel to pass through the main pump to the carburetor when the main pump is not operating?
2. What is the function of the fuel-pump relief valve?
3. If either of the valves concerned in questions 1 and 2 does not operate satisfactorily, what is probably the trouble?
4. In a periodic engine check-up, what are some things you should check on
   (a) fuel lines?
   (b) fuel tanks?
5. To maintain a constant pressure at the carburetor, __________ must be provided on the pressure side of the fuel pump.
6. Main fuel pumps are mounted __________.

7. To adjust the pump-discharge pressure, it is necessary to charge the compression on the __________ valve spring.
8. If you find any accumulation of water, rust, dirt, small metal or rubber particles, or an unique amount of sediment in the fuel strainers, you should __________.
9. The purpose of the engine-driven fuel pump is to deliver a ________ supply of fuel at the __________ and at all times during operation of the airplane engine.
10. At the present time the relief valve is built __________.
    a. in the intake line.
    b. in the exhaust line.
    c. into the fuel pump.
    d. in the drive shaft.
11. The bypass valves are held closed by the pressure of the fuel on the __________ side of the pump.
12. The auxiliary fuel pump __________ upon the engine to drive it.
13. When the auxiliary fuel pump is used as a booster pump it is hooked in series with __________.

CHAPTER 5

CARBURETION

PRINCIPLE OF CARBURETION

Modern airplane-engine carburetors are designed to be efficient, reliable, light and compact, and, as a result, they appear to be complicated devices with many intricate and ingenious mechanical features. While it is true that these carburetors do present a rather formidable appearance, yet when they are laid out in the open and each functioning part is viewed separately, carburetors should hold no secrets that you cannot readily understand.

The subject of carburetion was touched upon at the beginning of this book, but just superficially, and only to the extent necessary to show you its relation to the fuel system in general. At this point it will be treated more completely, because it is impossible to overemphasize the importance of understanding the theory of carburetion and not merely the mechanical functioning of two or three types of carburetors. Only by a thorough knowledge of the underlying principles is it possible for you to understand the purpose of each division or system of the carburetor, and to know why it is needed, and the effect that it has on the operation of the engine.

When a hydrocarbon—a chemical compound consisting of only hydrogen and carbon—is used as fuel in internal-combustion engines, it must be combined in certain proportions with oxygen to insure efficient burning. The hydrocarbon receives the oxygen from air—which is composed of approximately 3½ parts of nitrogen and one part of oxygen. This process of mixing fuel and air is called carburetion, and the device used to accomplish the mixing is called a carburetor.

The purpose of carburetion is to obtain a combustible

mixture. Combustion is merely the chemical combination of fuel with oxygen accompanied by the liberation of heat. In an airplane engine, the duration of combustion of the fuel charge should not exceed one-sixth of a revolution of the engine, which would be $\frac{1}{210}$ second if the engine is making 2,100 revolutions per minute. Not exactly time enough for lunch, or even for a couple of drags on a cigarette, but, nevertheless, the entire combustion of the charge is accomplished in this time. To make this possible, the fuel must be broken up into such small particles that it vaporizes in the air surrounding it.

You have heard of dust explosions. These are not uncommon in coal mines, in grain elevators or storage bins, and in other places in industry where there are large amounts of dust. It might be difficult to ignite this dust if it were concentrated in one solid object, such as a lump of coal. Coal will burn—but try to light a piece with a match. Certainly, by the wildest stretch of the imagination, you would never think of coal as an explosive material. But when coal is powdered into dust and mixed with air, it can be highly explosive. Many serious mine accidents have occurred because of this fact.

Gasoline, on the other hand, is thought of as an explosive liquid, yet, as mentioned previously, it can be burned in a lamp or even in an open pan without exploding. When the gasoline is finely divided, as in a spray, or what might humorously be called "gasoline dust," it will burn so rapidly that it may be considered as exploding. The reason? When gasoline is broken up into thousands of tiny droplets, much of its surface is in contact with the air. Now, the gas known as oxygen which forms a part of this air is not combustible—that is, it won't burn by itself—but nothing else can burn without it. It is the purpose of the carburetor then to turn the liquid gasoline into the smallest possible particles, which may be referred to as "gasoline dust" or vapor, so as to expose as much of the fuel as possible to the oxygen of the air.

Volatility is the ease with which a liquid evaporates. The higher the volatility, the lower the temperature at which the liquid will boil. Accordingly, high volatility is desirable

for easy starting, proper mixing of the fuel and air, less dilution of the lubricating oil, and usually better antiknock rating. On the other hand, if the boiling point is too low, the gasoline will evaporate or boil in the fuel lines, producing what is known as vapor-lock. As you are going to run across this term quite often in your work, let's see what it means.

When the liquid gasoline in the fuel lines is, for any reason, exposed to heat above the boiling point of the fuel, the gasoline vaporizes. The presence of vapor in any part of the line designed to handle liquid only, may block or exclude the flow of the liquid, resulting in a partial or entire starving of the engine for fuel. Because the boiling point lowers as the altitude increases, the danger of vapor-lock increases with altitude. This tendency has been overcome largely by the use of pressure-control systems and booster pumps to maintain a uniform pressure in the fuel tanks, and reduce the vapor-liquid ratio of the fuel in the lines, as already described.

Carburetor icing is another condition that is closely related to volatility. It is caused by the lowering of the temperature in the mixing passages of the carburetor as a result of vaporizing the fuel. When the fuel changes from the liquid to the vapor state, it actually draws heat from its surroundings. The more volatile the fuel, the more rapid will be the heat extraction from surrounding bodies and the air at the point where the vaporization takes place. The amount of heat extracted when fuel is changed from a liquid to a vapor state may lower the temperature of incoming air to a point where moisture in the air will condense and freeze on carburetor mixing passages.

As far as the tendency of the carburetor to ice can be controlled by fuel specification, fuels must be selected that will abstract the smallest amount of heat from their surroundings when they change to the vapor state, and still be satisfactorily volatile. The addition of sufficient heat to the incoming carburetor air or a design of carburetor mixing passages that will not permit ice to form, is a more satisfactory way of preventing icing, rather than by changing the fuel specification.

WHY USE GASOLINE?

There are a number of fuels that can be used with more or less success in internal-combustion engines. Some that might be mentioned in addition to gasoline are benzol—a coal, or coal-tar product, alcohol, crude oil, and kerosene, to say nothing of the gaseous fuel carried in "blimps" on the top of many European cars, and the gas from charcoal and wood burners employed so ingeniously in many foreign countries. But through many tests and experiments it has been determined that gasoline is the best and most practical fuel for high speed engines, and is the only one used in Navy reciprocating engine planes at the present time.

WHY IS GASOLINE BETTER?

In the first place it is cheaper than some of the other fuels mentioned. However, combat aircraft must have the best fuel regardless of cost. There are other important reasons. Gasoline has a better rate of burning than other liquid fuels, that is, the flame spreads through the fuel charge to better advantage, and it has a higher heat value per pound. Gasoline is made by the distillation of crude petroleum. The vapors are led into different condensing pipes. In this manner light, high-volatile gasoline is led into one tank; medium-weight, average-volatile gasoline is led into another; and the heavy, low volatile gasoline is led to a third tank. By blending these various types, almost any fuel requirement may be met.

IS ALL GASOLINE SUITABLE?

By no means. In testing gasoline for use in airplane engines, it is checked from four different angles. These are volatility, purity, antiknock rating, and heating value. The volatility determines the ease of starting and the distribution to the engine cylinders. Purity means the freedom from any substance that may be harmful to the engine. Antiknock rating indicates the maximum pressure and temperature that can be used in the engine without knocking. The heating value refers to the heat liberated by the burning of a unit weight of the fuel.

Airplane fuel must be free of any foreign substances such as water, dirt, acid, or alkali. It must be non-corrosive, low in sulphur content, and free from gum. Sulphur has a corrosive action on the parts of the fuel system and engine, especially those parts made of copper or brass. Gum has a tendency to deposit in the fuel system and on valve guides. An excessive amount of gum will cause such troubles as sticking valves and plugging or restricting the fuel passages. In other words, it will "gum up the works" in general. Gum is caused by a process of slow oxidation, and it is the general practice for oil refiners to put some agent into gasoline to prevent the formation of gum while the fuel is in storage. Water should be removed from the gasoline by straining it through a chamois or very fine screen filter.

WHAT IS OCTANE RATING?

Most gasolines, if used alone, will produce a sharp metallic knock when the engine throttle is opened up. Knocking never does much good, under any circumstances, and particularly in an engine, where it is not only harmful but is wasteful of power and fuel. The knock is easily heard in automobile engines, and if other sounds could be filtered out, it would be just as audible in the airplane engine. But it is generally necessary to depend upon instruments rather than the ear to detect such knocks, or detonations, as they are usually called, in an airplane engine Fuel knocks, or detonations, are accompanied by a rise in temperature of the cylinder heads, and this is an indication that can be measured.

In order to distinguish different grades of aviation gasolines, they are given as an octane rating. This rating refers to the antiknock properties of the fuel, and it takes its name from the method used in testing the knocking characteristics of various fuels. It would only be confusing to describe here the laboratory process by which such characteristics are determined. It is considered sufficient for the purpose to say that iso-octane—which is a fuel having exceptionally high antiknock characteristics—and another fuel called heptane—which is a bad "knocker" as compared to gasoline—are mixed together in different percentages until the anti-

knock value of the mixture when burned in a test engine, equals that of the fuel to be rated. The percentage of iso-octane in the test mixture when the knock corresponds to that of the gasoline is taken as the octane number of the gasoline. From this you may readily see that the higher the octane rating of the gasoline, the better the antiknock qualities.

It is a difficult matter to refine gasoline sufficiently for it to have a satisfactory antiknock rating for the modern engine. Accordingly, the antiknock rating is improved by the addition of some other liquid, tetraethyl lead being the compound generally employed for this purpose. The few difficulties encountered as a result of corrosion tendencies of ethylized gasoline are insignificant compared with the results obtained from the high antiknock value of the fuel. Even most of these tendencies have now been removed by special treatment of the fuel.

Since an octane number of more than 100 cannot exist (or at least cannot be measured in terms of octane) tetraethyl lead added to pure iso-octane is used to measure the knock value of fuels with an octane number of more than 100. When this system is used the antiknock quality is spoken of as performance number rating rather than octane rating and the fuel is rated as grade rather than octane.

The antiknock compound used in gasoline is composed of tetraethyl lead, ethylene dibromide, halowax oil, and analine dye, the function of each ingredient being as follows:

TETRAETHYL LEAD is the ingredient that eliminates the knock. It dissolves in gasoline in all proportions, vaporizes easily and completely, and is colorless.

ETHYLENE DIBROMIDE is a colorless compound which prevents corrosion of spark-plug electrodes, valve seats, and valve stems.

HALOWAX OIL is an extremely efficient lubricant that keeps the exhaust-valve stems from becoming dry. This in turn prevents the sticking and burning of the valves.

ANALINE DYE is used in very small quantities for identifying the octane rating or performance numbers of the fuel.

Navy aviation gasoline is identified as follows: 73 octane is clear or unleaded, 91–98 is blue and 115–145 is purple. As can readily be seen this identifies the fuel to be used in various engines and avoids using fuel of the wrong octane or performance numbers. The dye has no effect whatsoever on the performance of the gasoline mixture, it is merely for purposes of identification.

Naval aviation does not permit the addition of more than 4.6 milliliters of tetraethyl lead to a gallon of gasoline, as any amount in excess of this has very little effect on the antiknock value, but does greatly increase the danger of corrosion and spark-plug trouble.

Ethylized gasoline is intended solely as an engine fuel, and should never be used for the various other purposes for which ordinary gasoline is used. You will do well to keep the following "do nots" in mind when handling gasoline treated with lead.

Do not use ethyl gasoline for cleaning tools, machinery, clothing, or hands.

Do not spill ethyl gasoline on the floor of the hangar or on the airplane.

Do not place anything in your mouth after handling ethyl gasoline or parts of the exhaust or fuel system of an engine using it, without first washing your hands thoroughly.

If ethyl fuel is spilled on your clothes, remove them as soon as possible, and if it touches your skin, wash any such parts of your body with soap and water.

By taking advantage of present fuels of very high antiknock characteristics, it has been possible for engine designers to use much higher compression ratios, thus utilizing more of the power available in a gallon of gasoline, and increasing the power output per pound of weight of the engine.

There is a frequent and erroneous belief that more power can be obtained by using a higher octane fuel than that for which the engine was designed. If an engine is free from knocking when using a 90-octane fuel, there is nothing to be

gained by using 100-octane fuel, unless mechanical changes are made in the engine to increase its compression ratio.

The fuel now used in Navy aircraft is usually 115–145 for engines over 1,800 cubic inches displacement, with engines under 1,800 cubic inches displacement 91–98 octane is usually used. Clear or unleaded gasoline will be used only in auxiliary engines. The octane rating for a given engine will be found in one of the following places.

Manufacturer's name plate attached to engine; numbered placards on intake pipes; fuel-tank caps or cover plates; or on a placard adjacent to fuel-control cock.

THE WHY OF THE CARBURETOR

The carburetor must do two important things. One, meter—or measure out—the incoming fuel and air in such a manner that the charge entering the cylinders is of the proper proportions under all conditions of operation. The other, convert as much of the liquid fuel into a gaseous state as possible.

METERING of fuel and air is performed by five different systems in the carburetor in order to satisfy the engine requirements under all conditions. These are the MAIN METERING SYSTEM, the IDLING SYSTEM, the ACCELERATING SYSTEM, the POWER-ENRICHMENT SYSTEM, and the MIXTURE-CONTROL SYSTEM.

The details of the various systems that combine to make up the complete carburetor vary in different types of carburetors. It is therefore difficult to present a general explanation of the operating principle of any one system that will apply to all types. In view of this fact, it is considered sufficient at this time to outline briefly the reason for each system, and leave the details until later in connection with the description of the carburetors on which the various systems are used.

The MAIN METERING SYSTEM consists of a VENTURI—which will be described later—through which the air must flow on the way to the engine, and some means of controlling the amount of air. This arrangement gives an increase in veloc-

ity and a decrease in pressure of the air. These conditions are necessary for the operation of the carburetor.

The system also consists of a fuel-metering—or measuring—jet, which is usually merely a restricted opening in the channel through which the fuel flows into the carburetor. The size of this jet varies according to the fuel required by the engine.

Another important member of the main metering system is some form of nozzle that discharges the fuel into the air stream passing through the carburetor. The functioning of both the metering jet and the discharge nozzle is influenced by the density of the incoming charge, and the amount of opening in the passage leading to the engine. This passage is controlled by means of a variable opening device, known as a throttle.

The fuel passing through a discharge nozzle of metered capacity will have a natural tendency toward becoming richer—that is, increasing the proportion of fuel in the mixture—as the altitude increases. This enrichment is the result of the fact that the atmosphere gradually decreases in density at the higher altitudes. At 20,000 feet, for instance, the air is only about half as dense as at sea level. The volume and velocity of the air passing through the carburetor would be practically the same as at sea level, and therefore the amount of fuel picked up in the air would be about the same. However, since the air is "thinner" or not so dense, the air-fuel ratio would be altered by an increase in the fuel proportion. This characteristic is shared by all carburetors, and some means must be provided to overcome, or compensate for, this tendency toward richness at higher altitudes. The means usually employed—as will be explained further on—is a mixture control, which automatically maintains the proper fuel-air ratio regardless of altitude or other varying conditions.

The intake manifold plays an important part in the carburetion system, because of its effect on the distribution of the mixture charge to the different cylinders of the engine. The distribution is influenced by the design of the intake

manifold, because the manifold affects the velocity of the mixture in passing through it; by the heat applied to the mixture in passing through the supercharger and the manifold; and also by the relative size of the manifold branches.

That part of the carburetion system which connects the carburetor to the engine cylinders, and conveys the fuel mixture from the carburetor to the cylinders, has been referred to as the intake manifold. This term is O. K. with respect to automobile and in-line airplane engines, but is not appropriate as applied to modern air-cooled radial airplane engines. On the latter-type engines, there is normally no intake manifold, but the fuel-air mixture, after leaving the carburetor, passes through the supercharger, diffusion chamber, and distribution chamber, respectively, and then to the individual cylinders through separate intake pipes, which are of equal length and form.

THE IDLING SYSTEM

The fuel-air ratio of the mixture must be greater for low speeds than for speeds in the higher ranges, except when full engine power is required. At low speeds, the main fuel jet may deliver little or no fuel, because the throttle valve is

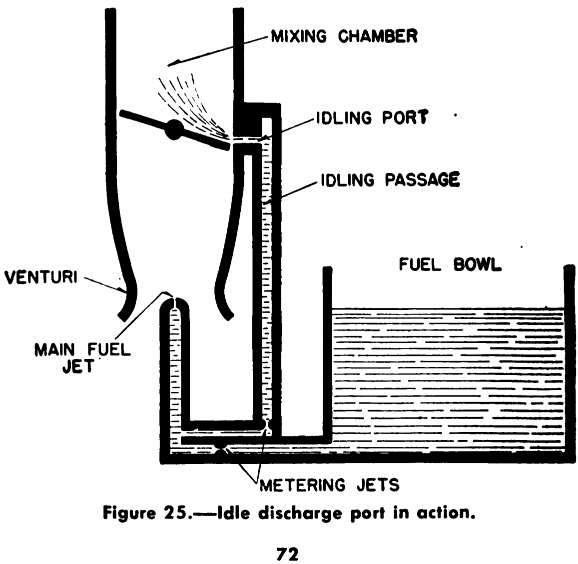

Figure 25.—Idle discharge port in action.

nearly closed, and there is little air drawn past the main jet. An idling passage is usually provided to carry the fuel up to a port at the upper edge of the throttle valve, when the valve is in its idling or low-speed position, as you will see in the diagram, figure 25. The idling system is thus practically independent of the main metering-jet fuel at low speeds only. As the throttle valve opens, the suction on the idling port decreases and that on the main jet increases, so that a point is reached at which the main jet takes over entirely and no fuel comes from the idling port.

THE ACCELERATING SYSTEM

In the horse-and-buggy days the usual method of speeding up the family chariot was to give a quick shove on the reins—lines, they called them—accompanied by a sharp, persuasive clicking of the tongue. The modern method—omitting the tongue clicking—does not vary greatly from the time-honored one, the only difference being that you now shove on the throttle instead of the lines.

The old mare did not always respond to the line shoving. Earlier cars usually showed a similar contrariness, for instead of the car leaping forward as anticipated, a sudden pressing of the throttle pedal resulted in a "flat spot," and the engine actually slowed down instead of speeding up. The reason for this condition is that when the throttle is opened suddenly, some time is required for the fuel stream to build up so that there will be the same ratio of fuel to air in the mixture going to the cylinders as is supplied by the carburetor.

A sudden opening of the throttle valve results in a decrease in the suction at the idling jet. This causes a delay between the time that the idling jet stops functioning, and that at which the main jet takes over, because there isn't sufficient air flowing through the carburetor at this time to cause the main metering jet to start functioning.

When no provision is made to counteract this lag in the fuel stream—as was the case with the earlier-model carburetors—there will be a temporary condition of "leanness" at

the cylinder immediately following a sudden opening of the throttle valve.

Modern carburetors are equipped with an accelerating system, which delivers an oversupply of fuel during the accelerating period. During a slow opening of the throttle, the accelerating system is inoperative, because the fuel pressure built up during such a motion is insufficient to produce the extra fuel required for acceleration. Otherwise, the presence of the accelerating system would result in an overrich mixture every time that the throttle is opened.

Three general types of accelerating systems have been in use in airplanes. In one case a well is employed, which supplies surplus fuel to the main nozzle when the throttle is opened quickly.

In another method, which is the one in broad use in Navy airplanes, an accelerating pump is operated by the throttle lever. By means of this device, fuel is pumped directly to the main-discharge nozzle or to a special accelerating nozzle.

The third type utilizes the pressure of a diaphragm to force additional fuel into the air stream.

ACCELERATOR PUMP

The operation of an accelerator pump is shown in the diagrams, figure 26. The pump is shown as located in the float chamber, but in the actual carburetor it fits into a separate chamber that is in communication with the float chamber, and also with a passage to a spray nozzle that extends into the venturi tube.

By referring to figure 26, you will observe that the pump consists of an inverted sleeve, or cylinder, resembling a diving bell, which has a stem at the upper end operated by the throttle lever. Within the sleeve is a piston that is free to slide on a hollow stem screwed into the main body casting. The upper end of this stem is shaped like a small poppet valve, and several holes in the wide face of the valve lead into the central hole. The piston forms the valve seat, the piston being held against the valve by a spring. The center hole of the stem connects with a passage leading to the main-dis-

charge nozzle, or to a separate discharge nozzle located just below the edge of the throttle valve.

When the throttle is closed, the accelerator cylinder is in its top position, as shown in view (A), and the space within it is filled with fuel. When the throttle is opened rapidly, the cylinder moves down quickly, and the pressure of the fuel above the piston forces the piston down and away from the

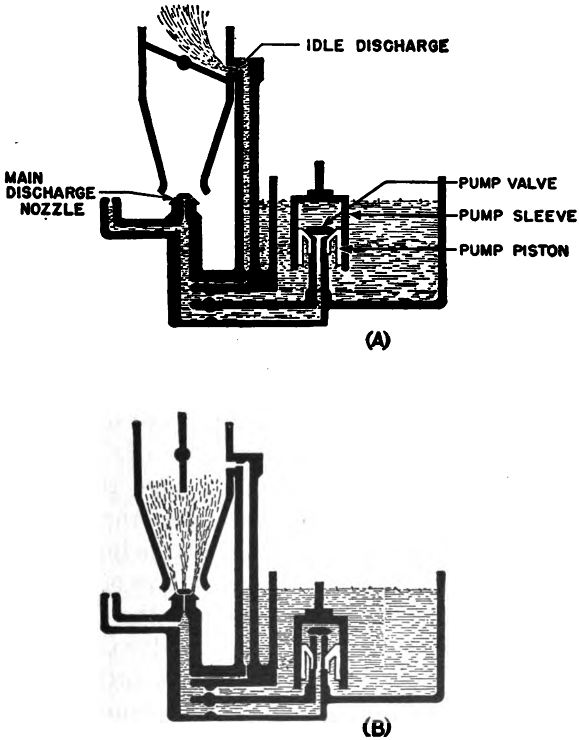

Figure 26.—Principle of accelerator pump.

poppet-valve top of the stem, thus uncovering the holes in the valve. The downward moving cylinder forces the fuel out of the discharge nozzle, as shown in view (B). The spring then moves the piston up and forces the fuel trapped between the piston and the valve head out through the discharge nozzle. Thus, the fuel discharge continues even after the

throttle has reached the wide-open position. If the throttle remains open, the fuel flow through the accelerating system will stop as soon as the piston reaches the valve.

As the throttle is again partly or entirely closed, fuel is drawn into the pump cylinder through the clearance space between the piston and the cylinder. This arrangement provides automatic regulation of the fuel charge, depending upon the speed of throttle opening. If the throttle is opened slowly, the fuel passes through the clearance space and back to the float chamber, without giving the engine an accelerating charge. You may have used a tire pump in which the plunger was a loose fit. When you pushed the handle down slowly, you would feel no resistance to its movement, but if you shoved it down quickly a definite air cushion could be felt under the plunger. This illustrates the action of the accelerator cylinder.

For use on engines that require a large accelerating charge for cold-weather operation only, a restriction may be used to reduce the charge of fuel during warm-weather operation. This arrangement makes it possible to obtain smooth and positive acceleration under all conditions of operation, without changing the metering characteristics of the engine.

Other types of accelerator pumps have the cylinder or sleeve fastened to a boss at the bottom of the float chamber by a special nut, which encloses a small spring-loaded check valve. A piston fits in the sleeve and is operated by the throttle. When the throttle is opened, the fuel under the piston is forced out through the check valve to the discharge nozzle. During operation at any fixed throttle position, the check valve remains closed and thus prevents any fuel discharge through the accelerating system.

Though the amount of the accelerating charge of fuel is limited when the throttle is opened suddenly, if the throttle is worked back and forth rapidly while starting an engine, a great quantity of excess fuel will be pumped through the discharge nozzle. If the engine does not start immediately, the gasoline will run down into the air scoop on an updraft carburetor. This may result in a dangerous fire if the gaso-

line is ignited by a backfire, or in some other way. In the case of a downdraft carburetor, the gasoline will run down into the induction system and result in damage to the cylinders. It may run out on deck through the supercharger drain tube, thus creating a serious fire hazard.

Prime the engine only with the priming system designed for that purpose, and do not attempt to prime by working the throttle lever back and forth.

POWER ENRICHMENT

The proportion of fuel to air—or the fuel-air ratio—must increase as the engine approaches full power. To obtain this result, various forms of enriching devices—usually referred to as economizers, or compensators—are employed in modern airplane carburetors. Applying the term economizer to an enriching device may seem somewhat confusing because it implies the opposite effect. The idea is that it would not be possible for the engine to run on the leaner mixture suitable for cruising or lower-power speeds were not some means provided to give the mixture the richness required for high power. Without the economizer it would be necessary to operate the engine at or above the best-power mixture over the complete power range.

When the engine is operating in the higher horsepower range, more heat is being liberated as a result of the increased quantity of gasoline and air necessary for the higher output. The cooling system of air-cooled engines is inadequate for proper cooling under these conditions. The economizer causes additional fuel to be sent to the engine, thus cooling the engine and increasing the power.

There are different types of economizers, or power compensators, used in modern carburetors which will be discussed in later chapters in connection with the descriptions of typical carburetors on which they are used. There are three general types, namely, the throttle-operated needle-valve type, the automatically operated needle-valve type, and the manifold-pressure type. These types may be described briefly as follows:

The throttle-operated needle-valve type consists of a pointed valve (see fig. 27) that controls an auxiliary fuel channel leading to the main-discharge nozzle. This valve begins to open when the throttle valve has opened to a predetermined point. As the throttle continues to open, the needle valve follows suit, and the fuel flowing through the needle valve causes a richer mixture, because it increases the fuel supply to the main discharge nozzle.

In the automatic needle-valve type of economizer, the valve is held in its seat by a spring. An auxiliary venturi is provided in the fuel inlet of the carburetor. When there is a flow of fuel through the venturi, the pressure at the throat is less than the pressure at the entrance. The greater the fuel

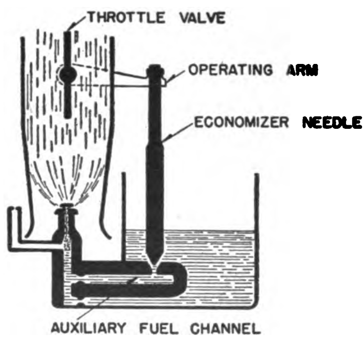

Figure 27.—Needle-valve type economizer, throttle operated.

flow through the venturi, the greater the difference in pressure between the entrance of the venturi and the throat. This difference in pressure is used to operate the compensating valve. When the fuel flow is increased to a point where the pressure in the venturi equals the initial pressure of the spring, the needle valve starts to open. Further increase in the fuel flow through the venturi causes an increase in the lift of the valve. This valve supplies additional quantities of fuel directly from the fuel entrance to the compensator discharge nozzle. The compensator supplies automatically the added fuel required to give the richer mixture desired at higher power outputs.

The manifold-pressure operated system depends directly on the manifold pressure for its operation and not on the extent of the throttle opening. At any specific altitude the amount of manifold pressure depends on the throttle opening. That is, when the throttle opening is held constant, and the altitude at which the engine is operating is increased, the manifold pressure will decrease, because the air becomes less dense. Though the same volume of air enters the carburetor, the weight of the air is less, and it is on the weight of the air that the manifold pressure depends. Therefore, in order to keep the manifold pressure at the proper value, the throttle opening must be increased as the altitude increases. Since the manifold-pressure economizer will not open until a certain manifold pressure is reached, regardless of the throttle opening, the mixture will be correct throughout the entire economizer range.

MIXTURE-CONTROL SYSTEM

As the airplane rises, it passes through atmosphere that is constantly decreasing in pressure, temperature, and density. When the air is thinner, that is, at a lower density, a pound of air will occupy a greater volume. Therefore, as the airplane ascends, for each pound of air taken into the engine, a greater volume of air will have to pass through the carburetor. The volume of air passing through the carburetor mixing chamber and the fuel discharged from the nozzle are both proportional to the suction.

As the airplane gains altitude, the volume of air passing through the carburetor continues to remain proportional to the suction, but the weight of the air passing through the carburetor decreases as the density decreases. With the amount of fuel from the carburetor discharge nozzle remaining proportional to the suction, it follows that more pounds of fuel will flow from the discharge nozzle per pound of air passing through the carburetor, as the air becomes less dense. Hence the fuel-air mixture will become richer as the airplane rises.

In order to compensate for this tendency of the carburetor

to give a richer mixture at higher altitudes, either a manually operated or an automatic mixture-control is employed. The mixture supplied by the carburetor may be made leaner by reducing the effective suction on the metering system by restricting the flow of fuel through the metering system, or by admitting additional air into the induction system through an auxiliary air entrance.

Each of the systems mentioned will be taken up later in connection with the carburetors on which they are used.

COMBUSTIBLE MIXTURES

There is a wide range of combustible mixtures of air and gasoline. Any ratio from eight to eighteen pounds of air per pound of gasoline will produce combustion in an internal combustion engine. Neither end of this scale will produce enough power to be very practicable, so we will consider only those ratios which can be efficiently used. Theoretically, fifteen pounds of air must be supplied to completely burn one pound of gasoline. This is known as a CHEMICALLY CORRECT MIXTURE. In order to get economy at cruising speeds, a mixture which is leaner than a chemically correct mixture will be used. This mixture will be 16 or 17 pounds of air per pound of gasoline and is known as the CRUISING or ECONOMY MIXTURE. If power is the primary consideration, a mixture known as the FULL POWER MIXTURE, consisting of 10 to 11 pounds of air per pound of gasoline will be used. Where moderate power is needed, RICH BEST POWER MIXTURE is used. This consists of 12–13 pounds of air per pound of gasoline. The idling mixture will be the richest of all. It consists of 9 to 10 pounds of air per pound of gasoline.

Briefly stated the usable combustible mixtures are:

IDLE—9 to 10 pounds of air per pound of gasoline.

FULL POWER—10 to 11 pounds of air per pound of gasoline.

RICH BEST POWER—12 to 13 pounds of air per pound of gasoline.

CHEMICALLY CORRECT—15 pounds of air per pound of gasoline.

An important point to remember is that fuel is always metered in proportion to the WEIGHT of the air, not the volume.

EFFECT OF IMPROPER MIXTURES

A mixture that is either too rich or too lean will cause the engine to lose power. Experience has shown that a lean mixture will burn slowly, and if the mixture is excessively lean, it will often be burning after the exhaust valves have opened to clear the cylinders. This excessive burning results in the engine overheating since the burning gases are discharged into the exhaust manifolds and the heat of explosion is carried to the cylinder bottom. In some cases, the gases will continue to burn until the inlet valves begin to open, and will cause premature ignition of the incoming charge, producing what is termed a backfire through the intake system.

As a general rule, maximum power is obtained with a mixture richer than the theoretically perfect mixture, but as maximum power is required only for the "take-off," it is not necessary to waste fuel by using a rich mixture for ordinary operation. An excessively rich mixture will cause the engine to roll—alternately speed up and slow down—when idling, and will result in incomplete combustion, loss of power, irregular firing, and overheating. If the mixture is considerably too rich, a certain amount of gasoline vapor will be consumed when the ignition takes place, leaving the remainder unburned. The vapor thus remaining may cause a second combustion if there is a flame present, or if the material with which it comes in contact is hot enough to ignite it. A mixture as rich as this will burn under atmospheric pressure with a yellowish flame, and leave a carbon deposit.

The proper mixture of gasoline and air for combustion purposes in an internal-combustion engine burns, at atmospheric pressure, with a blue flame and leaves little or no carbon deposit on the walls of the cylinders. Lean mixtures behave in the same way, except that when they burn in a confined space, the pressure produced is less than that produced by a perfect mixture. While the surplus air does not burn, it is heated and expands.

Table 1.—COLORS OF GASOLINE EXHAUST FLAME

Air-fuel (A/F) ratio	Color of exhaust flame	Condition of mixture
8.5 to 1	Bright yellowish-orange; black smoke.	Very rich.
9.5 to 1	Bright yellow	Rich.
9.7 to 1	Bluish white with faint yellow tinge.	Rich.
10 to 1	Light blue with trace of yellow	Rich.
11.3 to 1	Light blue	Slightly rich.
13.6 to 1	Intense light blue	Approaching ideal.
15 to 1	Light blue of maximum intensity.	Ideal.
17.3 to 1	Whitish blue of less intensity	Lean.

A closely blended and uniform mixture is necessary under all requirements—whether of economy or of power—and this must be obtained before the charge is ignited. This means early and rapid vaporization of the fuel, particularly at high engine speeds. Economy requires that, at the time of ignition, each particle of fuel shall be in contact with its proportion—or more than its proportion—of air. On the other hand, maximum power of an engine of definite size is obtained by burning the greatest practical amount of fuel, and, consequently, by supplying fuel somewhat in excess of the chemical combining proportion, in order to make use of the limited cylinder capacity to the fullest extent.

After you have had experience around airplane engines, your eyes will gradually be trained to a degree where you will be able to judge the correctness of the mixture by the color of the flame of the exhaust gases. Table 1 will assist you by showing the various conditions that are indicated by flames of various colors. Even the best carburetors are not perfect in their action throughout the entire speed range of an engine. Therefore, you should make your observations on the exhaust flame at or near full-throttle speeds, as the color may change somewhat at certain lower speeds without indicating that the carburetor is in need of adjustment.

FULL THROTTLE

As stated before, about 15 parts of air are required to 1

part of gasoline vapor for complete combustion—at atmospheric pressure—but gasoline will burn in an engine cylinder with only about 8 times its weight of air. Maximum power, regardless of fuel consumption, is obtained with a mixture of about 12½ parts of air to 1 part of gasoline. The temperature of air-cooled engines—especially at full throttle—is greatly affected by the fuel-air ratio of the fuel supplied to the engine, and rises very rapidly as the mixture is leaned out. For this reason, it is desirable to provide as rich a mixture as can be used at full throttle without loss of power during takeoff and periods of maximum power output.

CRUISING SPEED (PART THROTTLE)

At cruising speeds it is desirable to obtain the maximum power—not from the engine but from a given amount of fuel—in order to obtain maximum economy, and a leaner mixture is therefore required. The ratio for greatest economy is about 16 parts of air to 1 part of fuel.

CLOSED THROTTLE (IDLING)

When the throttle is closed at idling speeds the amount of air and fuel is greatly reduced as compared with wide-open throttle conditions, and there is a greater percentage of exhaust gas in the cylinder. Therefore, the mixture burns more slowly, and it is necessary to have a richer mixture at idling and low speed than that required for either maximum economy or maximum power.

The amount of exhaust gases left in the cylinders at idling is the same as at open-throttle positions. In an engine with a short exhaust stack, atmospheric air enters the cylinders through the exhaust valves because of valve overlap at intake, and also because of the low pressure existing in the intake manifold. A richer mixture at idling is required to correct this condition.

To sum up then, an excess of gasoline is required to make starting easier, and to run the engine at idling or low speeds; a rather rich mixture for greatest power; and a weaker mixture for economy. An excess of fuel is, to some extent, a cor-

rective for imperfect mixing and vaporization of the charge. For the purpose of cooling and for preventing knocking—especially in air-cooled engines—it may be necessary at full power to have a mixture ratio richer than one that gives the best power.

TEST YOUR MEMORY

In this chapter you have been given basic information that you will need in order to be able to understand the operating principles of carburetors, and to be able to apply these principles to the construction and operation of the actual carburetors as described in the following chapters. Before leaving the subject of carburetion, let us briefly review the functions that a carburetor must be capable of performing in order to qualify for use in a modern, high-speed, airplane engine. If you have read your book carefully so far, you will have found that the functions are as follows:

The carburetor must give a correct mixture, whether the demand on it is light or heavy, within the range of the speed actually attained by the engine, and regardless of altitude. The airplane engine seldom remains for any length of time at the same altitude while in flight, and the carburetor used on it must be capable of adjusting the mixture for varying air densities. The density of the air at an altitude of 20,000 feet, for instance, is only about half that at sea level.

The carburetor must not be too sensitive to changes in the quality of the fuel, and it must permit an easy adjustment for such ordinary variations of fuel as are likely to be encountered. This does not mean that the adjustment should be under the control of the operator, as, in many cases, carburetors are purposely designed without means of adjustment, being correctly set at the factory.

The carburetor must not be unduly affected by changes in the attitude of the plane, as when climbing, diving, or flying in the inverted position.

It must atomize the fuel efficiency for starting in cold weather, and supply sufficient fuel for a sudden increase of speed within a reasonable time.

The ratio of the mixture delivered must not be affected by the vibration of the engine.

The carburetor must not be exposed more than necessary to the entrance of dirt, and all parts exposed to dirt must be readily accessible for cleaning.

It must be provided with means of preventing the formation of ice.

You will appreciate more than ever the problems of designers when you stop to consider that all of the foregoing requirements must be met under the following conditions.

Straight flying; radical maneuvers and stunts; various climatic conditions, such as variable barometric pressure and variable temperature; variable fuel characteristics; variable altitudes; variable speeds; and even dust in the air and fuel.

The manner in which these requirements are accomplished will be discussed in the following chapters.

QUIZ

1. (a) What are the two basic functions of a carburetor?
   (b) Explain how one of these functions may be responsible for carburetor icing.
2. (a) What name is given to the condition of gasoline evaporating or boiling in the fuel lines?
   (b) Why is this condition dangerous?
   (c) Why is it more apt to occur at higher altitudes?
3. (a) What fuel characteristic is rated in octane numbers?
   (b) What is the chief operating advantage of using high-octane fuel?
   (c) Why is there no advantage in using a higher-octane fuel than that for which the engine is designed?
4. (a) What is meant by a "rich" mixture?
   (b) Why does the mixture naturally tend to become richer as the airplane gains altitude?
   (c) What part of the fuel system is designed to compensate for this natural tendency?
5. (a) What is the natural condition of the fuel mixture immediately after the throttle is opened suddenly? Why?
   (b) What part of the fuel system is designed to correct this condition?

6. An excessive amount of ____________________ will cause sticking valves and restricted fuel passages.
7. Octane number of over ____________________ cannot exist.
8. Ethylized gasoline should be used ____________________.
9. The main metering system of a carburetor consists of all but the ____________________.
   a. venturi.
   b. measuring jet.
   c. discharge nozzle.
   d. idling passage.
10. Prime the engine only with ____________________.
11. The best air-fuel ratio by volume for complete combustion is about ____________________.
12. Fuel knocks or ____________________ are accompanied by a rise in temperature in the cylinder head.
13. The ____________________ rating refers to the antiknock properties of a fuel.
14. ____________________ is used in small quantities for identifying the performance number of a fuel.
15. Clear or unleaded gasoline will be used only in ________________ engines.
16. The fuel-air mixture will become __________ as the airplane rises.
   a. richer.
   b. leaner.
   c. heavier.
   d. denser.

CHAPTER 6

FLOAT-TYPE CARBURETOR

GENERAL FEATURES

In its most elementary form, a fuel nozzle in the intake manifold of an engine is a carburetor. In fact, the old "one-lungers" which were the forefathers of the present sleek, high-powered cars, were equipped with a so-called mixing valve, which was practically nothing more than that. The simple carburetor illustrated in figure 28 is given only for the purpose of showing the elementary principles of operation of a float-type carburetor, and does not represent an actual type in use today.

The float chamber is supplied with gasoline from a fuel line shown in the illustration at the top of the chamber. As the gasoline rises in the float chamber, it raises a hollow float, which is carried on a lever that is hinged to the carburetor body. The float lever carries a needle valve, the point of which extends into an opening in the fuel line. When the float rises far enough, the needle closes the fuel intake. When gasoline is taken from the float chamber, the float lowers, and the fuel passage is once more opened. In this way a maximum fuel level can be established in the carburetor.

The discharge gasoline passage leads to a nozzle and the gasoline rises in the nozzle to a point about $1/8$ inch below its tip. The height of the fuel in the nozzle is controlled by the float and the needle valve in the float chamber. A choke tube—known as a venturi, to be explained later—surrounds the nozzle, and the throat or narrowest part of the tube is at the tip of the nozzle. Air is drawn into the engine past the nozzle and a butterfly valve, known as a throttle valve. At

the throat of the choke tube the speed of the air current is so increased that a suction is produced at the nozzle, raising the fuel the remaining 1/8 inch and causing it to be sprayed into the air stream—exactly as previously described in connection with the atomizer. If the nozzle has an opening of the proper size and the air flow is kept constant, the correct amount of fuel will come from the nozzle to produce a vapor mixture of about 15 parts of air to 1 part of gasoline, by weight.

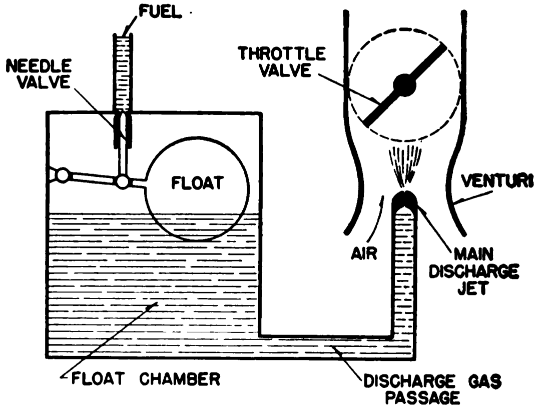

Figure 28.—Diagrammatic sketch of plain jet carburetor.

The quantity of mixture that passes to the engine cylinder is controlled by the throttle valve, which in the elementary carburetor shown consists of a thin disk fastened to a shaft that is turned by a lever connected by the necessary linkage to a manual control in the pilot's cockpit. There are many automatic parts to a carburetor, but the throttle valve, regardless of its design, is one part that is always under the direct control of the pilot.

The throttle valve is so arranged that when it is adjusted properly, closing it will not cause the engine to stop from lack of fuel, but will permit the engine to run at the lowest speed at which it will keep in motion. This is called the idling speed of the engine. The degree of opening of the throttle valve for the idling speed of the engine is adjustable by means of a setscrew—known as the throttle stop screw—carried on the throttle lever, or crank arm. In some types of car-

buretors, a second stop screw is provided to limit the maximum opening of the throttle. The fuel is filtered before it enters the float chamber of the carburetor, and means are provided for removing the fuel strainer for cleaning purposes.

The simple carburetor shown in figure 28 is of the updraft type, which means that the incoming air is drawn in at the lower part of the carburetor, and flows up past the discharge nozzle in the choke tube, or venturi. The mixture must be carried upwards against the force of gravity, and any loss of velocity results in some fuel particles dropping.

Another type of carburetor, known as the down-draft type,

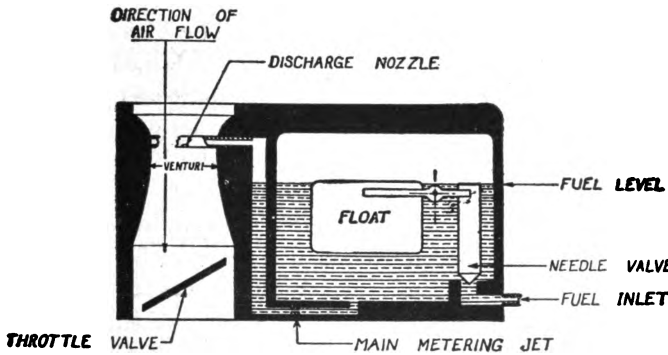

Figure 29.—Diagrammatic sketch of downdraft carburetor showing elementary principles.

an elementary form of which you will see in figure 29, is located relatively higher on the engine and has its air inlet at the top. Because of its location, it has less tendency to pick up sand and dirt, and in the case of seaplanes is less likely to be affected by spray during takeoff. Both types of carburetors are employed in late-model engines.

SPRAY CARBURETORS

All modern airplane carburetors are of the spray type, which means that they have one or more nozzles, or jets, each of which has one or more extremely small openings, or orifices. To simplify the explanation, assume at first that one nozzle is used and that the nozzle has only one opening.

The piston in an engine cylinder, on its suction stroke, creates a partial vacuum at the opening of the nozzle. Hence, gasoline is drawn from the nozzle in the form of a finely divided spray, which mixes with the air rushing at a high velocity past the nozzle. The spray nozzle is generally located centrally in the venturi tube, but in some carburetors it is mounted at an angle to the venturi. The nozzle opening is usually at or slightly beyond the narrowest part of the tube, where the suction is the greatest.

The major problem in designing a carburetor is to provide one that will give a proper mixture of gasoline vapor and air having a uniform composition, as required at all engine speeds and at all throttle openings. The elementary type of carburetor cannot do this, since, as explained before, the flow of gasoline from the spray nozzle increases at a greater rate than the flow of air through the venturi when the engine speed is increased. In other words, if the ratio of gasoline vapor to air—the fuel-air ratio—is correct at low engine speed, it will be too large at a higher speed, or, as it is commonly expressed, the mixture becomes too rich. This is the opposite way that the mixture should be, as it will be most satisfactory if it is a little rich at very low engine speeds, and becomes less rich—or leaner—as the engine speed increases. A carburetor that controls the mixture over only a small range of speed and throttle opening lacks flexibility. Conversely, a carburetor that controls the mixture properly over a wide range of speed and throttle opening is said to be very flexible. Flexibility in a carburetor can be secured by providing means of counteracting the natural tendencies of the device, as described, and a carburetor provided with such means is called a compensating carburetor.

HOW COMPENSATION IS ACCOMPLISHED

Two methods have been employed to compensate the simple jet so as to overcome its tendency to produce an increasingly rich mixture with increase of speed of the engine. One of these is by combining a simple jet, which will supply a mixture that grows richer as the suction increases, with a jet that

supplies a mixture that becomes leaner under the same conditions, the two being so designed as to counterbalance each other and thus give a continuously correct mixture. The other method of compensation is to use the so-called air-bleed principle, and since the Stromberg is the only float-type carburetor employed in Navy airplanes at present, and as this type operates on the air-bleed system, it will save confusion to limit this discussion to this one method.

WHY NOT USE PLAIN SPRAY NOZZLE?

The flow of gasoline from the spray nozzle of a plain carburetor of the type shown in figure 28, does not increase or decrease in direct proportion to the increase or decrease in the flow of air through the venturi tube and past the spray nozzle. As the vacuum at the plain nozzle increases because of the greater engine speed or throttle opening, the flow of gasoline increases more rapidly than that of the air. This is due in a large measure to the tendency of the fuel to cling to the nozzle. As the clinging tendency is constant at all engine speeds, the slow air flow, and consequent low vacuum, when the engine is running at low speed will have more difficulty in tearing away the fuel particles than will the rapid flow of air at high speeds and consequent high vacuum. The enriching of the mixture produced by a change from low speed to medium speed with such a simple jet, will, therefore, be proportionately greater than for a change from medium high to high speed.

THE AIR-BLEED PRINCIPLE

To understand the principle of the air-bleed carburetor, study the simple device shown in figure 30. It consists of a glass tube that extends into a liquid in a glass vessel with the lower end of the tube narrowed to form a small opening, or orifice. Since the term orifice is better suited to describe a small measured opening as used in carburetor jets, it will be used in the rest of this text. The orifice limits the rate at which the liquid can enter the tube.

From a point below the surface of the liquid, a small branch—the air bleed—leads from the main tube to the air. If suction is now applied with the mouth to the upper end of the main tube, liquid will be drawn into this tube through the orifice at the lower end. At the same time, air will be

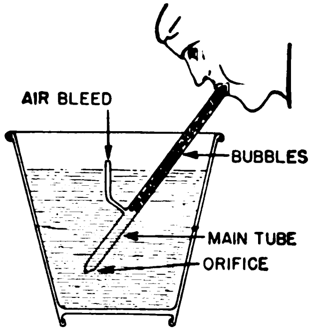

Figure 30.—Principle of air bleed.

drawn into the tube through the air-bleed branch, and this air mixing with the liquid will form an emulsion of air bubbles and liquid in the upper part of the tube. As this

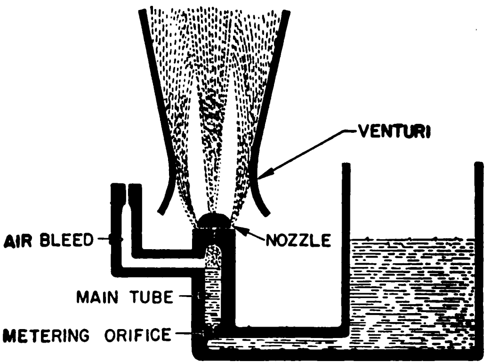

Figure 31.—Application of air-bleed principle.

emulsion is much lighter than the liquid alone, it may be drawn up the tube with less suction.

Now look at figure 31, and see how the principle just ex-

plained can be applied to a practical carburetor. The fuel enters the main tube through the metering orifice, and is sprayed from the tip of the nozzle by the suction existing in the throat of the choke tube, or venturi. The air bleed enters the main tube below the tip, and when the suction is applied, an emulsion of fuel and air bubbles is drawn from the nozzle openings. These openings, you will observe, are at right angles to the direction of the air flow, which assists in the atomization of the fuel.

IDLING

The discharge nozzle of a carburetor is located at the throat of the venturi tube, where the speed of airflow is the greatest. When the throttle valve is nearly closed, very little air will be flowing through the venturi tube, and practically no suction will be exerted on the discharge nozzles.

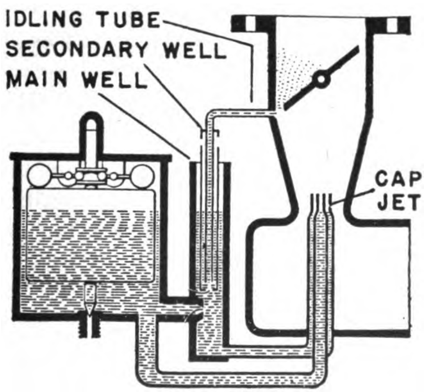

Figure 32.—Idle system with air bleed.

As it is necessary to provide some means of running the engine at very low speeds some source of fuel other than the main jet, or jets, must be provided. When the throttle is nearly closed, the maximum speed of airflow is past the edge of the valve instead of at the throat of the venturi tube. It is customary to locate the discharge orifice for idling fuel at the edge of the throttle valve.

When the cap jet (fig. 32) comes into action, the fuel level in the main well is lowered below the compensating jet, and consequently the idling device is put out of action. Under this condition, with the main well empty except for fuel flowing through its lower part, air is drawn in through the main and secondary wells, and mixes with the fuel supply delivered from the cap jet. As the emulsion thus delivered from the cap jet is thoroughly mixed with the fuel coming from the main jet, it may be considered that at high speeds the cap jet acts as an air-bleed for the main jet.

MIXTURE CONTROL

The greatest power is obtained in an airplane engine by using a slightly rich mixture, but for ordinary flight conditions the greatest power of the engine is necessary only for the takeoff. When the airplane gets into the air, the engine is throttled down and the problem then becomes one of obtaining the greatest economy. As has been emphasized several times, the density of the air decreases as the airplane gains altitude, and, with jets that give a proper mixture at sea level, the mixture becomes too rich at greater altitudes. A device is therefore built into airplane carburetors that will enable the pilot to vary the quality of the mixture as may be necessary to produce the best operating results. This device was formerly called the altitude control, but as its use is not limited to taking care of changes in altitude, it is now referred to as the mixture control.

The jets of the carburetor are set normally to give a slightly rich mixture at sea level, so as to obtain maximum power from the engine at the takeoff. Once the airplane is in the air, the mixture control is used to adjust the mixture for the maximum number of revolutions of the engine per minute for each throttle opening that may be used. In other words, by the use of the mixture control, it is possible to alter the ratio of fuel to air without changing the metering devices.

At any particular setting of the throttle, the mixture control must be varied throughout its entire range in order to take care of the changing conditions as the altitude is in-

creased from sea level to the ceiling of the airplane in which the engine is installed. In some cases, the performance of the airplane may be so limited that the foregoing statement will need modification, since some heavy-duty planes do not have a ceiling high enough to require the full use of the mixture control. The ceiling of the airplane, as you probably well know, is the altitude that it can reach, and the term may be used in two different senses. The absolute ceiling is the greatest altitude that a machine of given weight and power can attain. The service ceiling is the altitude at which the rate of climb is reduced to 100 feet per minute.

In order to obtain mixture control in a Stromberg carburetor, the mixture supplied by the carburetor may be made leaner by reducing the effective suction on the metering system, which restricts the flow of fuel through the system, or by admitting additional air into the induction system through an auxiliary air entrance. Each of these methods has been used.

FLOAT-CHAMBER-SUCTION CONTROL

The float-chamber-suction type of mixture control is sometimes called the back-suction, because the top of the float chamber leads to the barrel of the carburetor just above the venturi tube. This connection is provided with a valve that may be opened or closed by the operator. The suction of the engine in drawing the mixture from the carburetor causes the pressure inside the carburetor barrel to be much less than that of the atmosphere outside. Then if the valve is opened, air will be sucked from the top of the float chamber through the connection to the low-pressure area inside the carburetor barrel. Reduced pressure on top of the fuel supply reduces the rate of fuel flow through the orifices, and the amount of the reduction can be regulated by opening or closing the valve.

Under normal conditions at sea level, the regulating valve will be closed but at an altitude of about 6,000 feet the mixture will begin to be too rich, and the pilot will open the regulating valve slightly until the fuel flow is impeded sufficiently to give normal mixture.

You will be able to understand the back-suction-control method better by looking at figures 33, 34, and 35. These illustrations show a very elementary carburetor having a float chamber and float, an air venturi, and a fuel nozzle. On the top of the carburetor are two valves, the right-hand one being open to the outside air, and the one at the left-hand being connected to the suction line terminating in the throat of the venturi. In the view shown in figure 33, the air valve is open and the suction valve is closed. In these respective

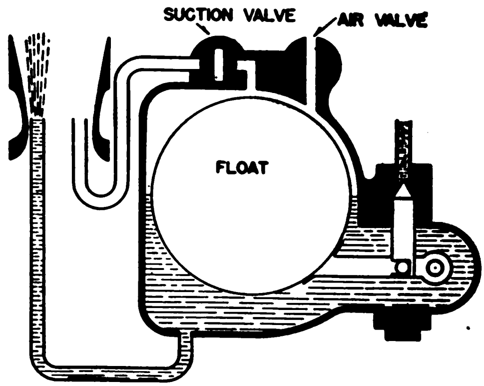

Figure 33.—Back-suction mixture control, full-rich position.

positions, you can see clearly that no suction is applied to the top of the float chamber, and the same pressure exists inside the float chamber as outside. Under these conditions (the mixture control is in its full-rich position) the carburetor will operate normally.

In figure 34, you will observe that the suction valve (at the left) is open and the air valve is closed. In this case, the suction on the suction tube is exactly equal to that on the fuel nozzle and there is no reason for the fuel to flow. The fuel will simply take the level shown. This, of course, represents the extreme "lean" condition that could be obtained with this type of control. This condition is never attained in practice, as some fuel must flow in order to allow the engine to run. In order to overcome the tendency to total leanness, the suc-

tion connection, as you will see in figure 35, is located above the fuel jet, or at a point of lower suction than on the jet. Also a small restriction is placed in the suction passage in-

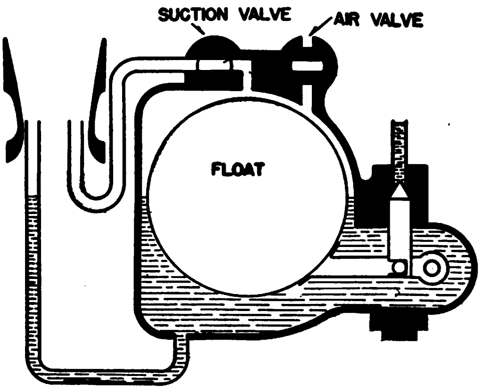

Figure 34.—Back-suction mixture control, extreme-lean position.

stead of a movable valve. With this arrangement, the air valve may be completely closed without entirely stopping the flow of fuel, since the suction above the fuel in the float chamber will not equal the suction at the discharge jet.

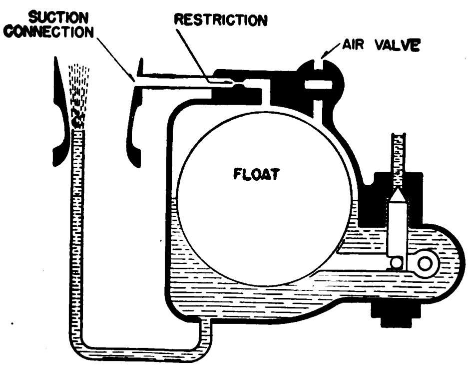

Figure 35.—Back-suction mixture control channel restriction.

In order that the action of the mixture control will not be too sensitive, the air valve must close rapidly at first and then more gradually. This is accomplished by using a flat

disk valve which closes off a good portion of the air-vent passage in the first few degrees of rotation, and then closes the vent more slowly during the remainder of the rotation. Take a look at figure 33 to see how the valve works. The under disk of the valve is stationary and the upper disk is free to revolve. The two parts are held together by spring pressure. With the valve in the position illustrated, all of the slot in the lower disk is uncovered. This gives the maximum venting of the float chamber, and prevents any suction in the top of the float chamber through a small drilled hole corresponding to the restriction in the suction channel. This is the full-rich position of the valve.

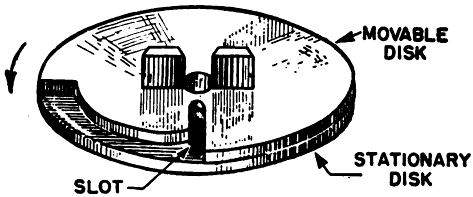

Figure 36.—Manual mixture-control valve.

If the upper disk is now rotated in the direction of the arrow, a slight degree of rotation will cover up about two-thirds of the elongated slot in the lower disk. This shuts off most of the outside vent, so that some suction is applied to the top of the float chamber by the suction line. This slows up the flow of the fuel through the spray nozzle, and results in a leaner mixture. Further rotation of the valve results in a very gradual reduction in the size of the slotted opening, because of the gradually decreasing width of the notch in the edge of the valve, which gives an accurate mixture control.

The actual construction and installation of the manual valve as used in NA–R9C2 and other carburetors, will be given further in this book.

NEEDLE-VALVE CONTROL

In the needle-valve type, figure 37, of manual control, also used in Stromberg carburetors, a needle valve is used to re-

strict the fuel passage to the main-metering jet. With the mixture-control in the full-rich position, the needle is raised as illustrated, and the fuel is accurately metered by the main restricted opening in the passage. The valve is controlled by a lever operated from the cockpit of the airplane. When the lever is moved toward the lean position, the needle is lowered into its seat, thus reducing the fuel supply to the main-metering jet. A small bypass hole leading from the

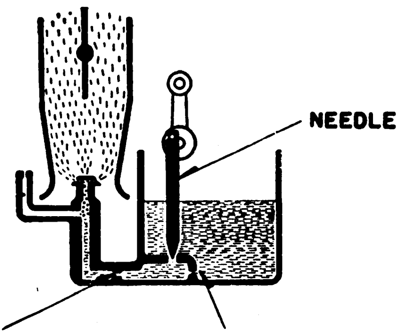

Figure 37.—Needle-valve type of manual control.

float chamber to the fuel passage permits some fuel to flow, even though the needle valve is completely closed. The size of the bypass opening determines the range of control.

ALTITUDE MIXTURE-CONTROL RANGE

The range of the mixture-control is usually stated in terms of altitude. This means that a carburetor having a correction range of 20,000 feet will give the same mixture ratio at this altitude with the mixture-control set at full lean, as at sea level with the control set at full rich. If a metering jet setting is used that gives a mixture richer than necessary on the ground with the idea of using the mixture-control to correct for this condition, the remaining control available for altitude use will be less than if the ground-level jet were correct with the control full rich.

The float-chamber suction type and the needle-valve type

of mixture-controls have a correction range of approximately 25,000 feet altitude. After the limit of mixture-control correction has been reached, the airplane can ascend 5,000 or 6,000 feet farther before the mixture will become rich enough to cause the engine to lose power, and several thousand feet more before the engine operation becomes excessively rough.

In some Stromberg carburetors using the back-suction control, an automatic mixture-control is substituted for the air valve on the float-chamber housing. This control will be explained later.

IDLING CUT-OFF

Considerable difficulty is sometimes experienced in bringing a high-power engine to a stop after the ignition is cut off. This is particularly true after the airplane has been run or taxied on the ground until the cylinder heads become very hot. In this case, the engine continues to run because of the incoming fuel being ignited by coming in contact with the overheated metal. The result may be a "back kick" with possible damage to the engine, especially if the engine is of the geared type with a heavy propeller.

To overcome this difficulty, an idle cut-off is provided in conjunction with the mixture-control disk valve. When the mixture-control valve is placed in the idle cut-off position, the float chamber is subjected to the full suction of the carburetor barrel through a passage opening into the barrel at a point above the throttle valve. When the throttle is closed, the suction on the top of the float chamber is sufficient to stop all flow of fuel from the chamber. Lacking fuel the engine will stop running.

APPLICATION OF PRINCIPLES

This discussion has been concerned chiefly with the underlying principles of carburetors, knowing how essential it is that you become grounded in these principles before you can hope to be able to understand their application to actual carburetor constructions. Before taking up representative types of carburetors, let's spend a little time in studying the

principal parts of the float-type—many of which apply to other types, as well—so that when you encounter them later in place in the carburetors, you will have, at least, a "speaking acquaintance" with them. You will probably find some repetition of information already given, but only by pounding repeatedly on important points can they become firmly fixed in your mind. A float-type carburetor consists of the following main parts.

The carburetor body, which contains the various units; the strainer, through which the fuel must enter the carburetor; the float and needle-valve mechanism, which controls the supply of fuel in the float chamber; the float chamber, which is a reservoir for fuel, so arranged that the fuel can be delivered to the discharge nozzles at a constant level; the venturi tube which is a passage with a narrowed part in which the discharge nozzles are centrally placed; the discharge-nozzle assembly, which is an arrangement of nozzles that discharge fuel into the air stream; the idling system, which is an arrangement for supplying a proper fuel mixture at low engine speeds when the main nozzles are not operating; the throttle, which controls the amount of mixture that enters the induction system; and the metering assembly, which is an arrangement of orifices for regulating flow.

THE CARBURETOR BODY

The body of the carburetor is made of cast aluminum to keep down weight. Care must be taken to see that all joints and fittings are tight, as even a very slight leakage of air may be sufficient to interfere with the proper operation of the engine. Joints are lapped so as to fit without gaskets, or are fitted with thin paper gaskets in order to insure the required tightness. The body includes an air horn, or scoop, the shape and location of which with relation to the air stream may have an appreciable effect on the running of the engine. A drain is provided at the lowest point of the air horn to carry off any fuel that may collect. Piping from this drain should lead clear of the airplane structure in order to reduce fire hazard. Plugs are provided at the ends of

passages through the carburetor body to provide for cleaning and for changing the meter orifices.

THE STRAINER

A typical carburetor strainer installation is shown in the sectional view of the carburetor float chamber in figure 38. The strainer consists of a screen of fine mesh, and its purpose is to remove dirt from the fuel before it reaches the needle valve. Dirt in the carburetor may prevent the needle valve from seating and thus flood the carburetor, or it may clog

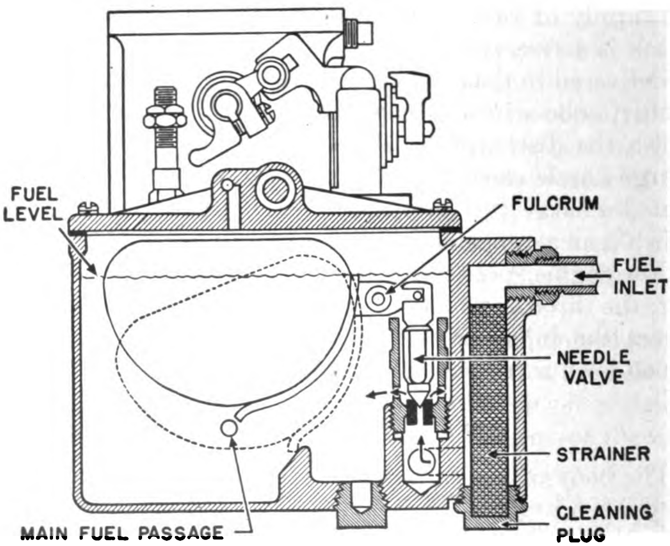

Figure 38.—Typical float system.

the metering orifices. The strainer is removable for cleaning by removing the plug that holds it in place.

FLOAT MECHANISM

In the float-type carburetor the fuel should be subjected to no other force than the action resulting from the airflow through the venturi. It is therefore necessary to provide a separate reservoir, known as a float chamber, between the

main fuel line and the metering system of the carburetor. Referring again to figure 38, you will see that the float, which, of course, is placed in the float chamber, is attached by means of a lever to a pointed valve—known as the needle valve—which cuts off the inflow of fuel from the supply line when the liquid rises to a pre-determined level. The combination of float and valve is known as a float feed.

With no fuel in the carburetor, the float takes the position shown by the dotted lines. In moving to this position, it raises the needle valve and opens the fuel inlet. When the engine is running and fuel is being drawn out of the float chamber to the jets, the valve does not alternately open and close, but takes an intermediate position such that the valve opening is just sufficient to supply the required amount of fuel and keep the level fairly constant. The float is set to maintain a fuel level slightly lower than the tip of the spray nozzle. This is done to secure a margin of safety to allow for inaccurate operation of the float and the valve, so that there will not be an excessive flow of fuel from the nozzle in case the float allows the liquid to rise slightly above its normal level. It also prevents dripping when the engine is idle, and overflow resulting from the tipping of the carburetor when the engine is out of level.

The seat of the needle valve is often made of brass and the needle itself of steel or monel steel. Stromberg carburetors use stainless steel seats and hardened stainless-steel valves. This difference in hardness is used in order that the unavoidable wear may be confined to the seat, so that it tends to conform to the shape of the needle. The opening of the needle valve is made larger than that required to pass the maximum amount of fuel required, in order that an ample supply of fuel may always be available at the metering orifices.

Hollow metallic floats are almost universally used because of their low cost, ease of construction, and reliability of service. The float is usually made of brass and is formed by spinning, pressing, or stamping. The float mechanism is designed to operate at fuel pressures of 2 to 4 p. s. i., 3 pounds pressure being recommended for service use.

FLOAT CHAMBER

An important requirement of the float chamber besides those requirements already mentioned, is that it be located as close as possible to the discharge nozzles. If it is too far from the nozzles, a distinct lag in the flow of fuel will be noticed when the throttle is opened rapidly. The float chamber must be vented, that is, opened to the air, so that fuel may flow into the chamber without compressing the air above the surface of the fuel and flow out of the chamber without producing a partial vacuum in the space above the fuel. Vents to the float chamber are usually led to some internal space in the carburetor body which is itself open to the outside air. This accomplishes the double purpose of reducing fire hazard due to the escape of fuel vapor from the vents into the open air, and of preventing erratic performance of the carburetor that might result from leading the vent to the disturbed air flow past the outside of the body.

MAINTAINING FUEL LEVEL

One of the most important requirements of an airplane carburetor is the maintenance of the fuel level with respect to the discharge nozzles. If the nozzle assembly is forward of

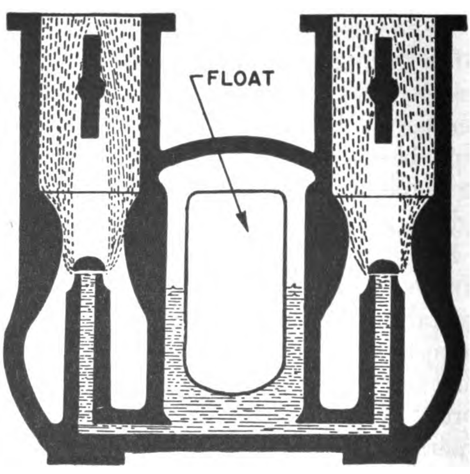

Figure 39.—Position of fuel discharge nozzles in duplex carburetor.

the float chamber, there will be a tendency to flood the nozzle when the airplane is diving and to starve it when climbing—which is exactly opposite to the usual demands of the engine for fuel in these attitudes of the airplane. When a duplex carburetor is used, the nozzles are usually located in a horizontal line extending laterally through the center of the float chamber, as illustrated in figure 39. This makes an ideal location as regards fuel supply when climbing or diving, but may result in flooding the carburetor nozzles for one bank of the engine while starving the other bank, in case the airplane is placed in a steep side-slip. As this is not a normal flying attitude, this objection is not important.

Alterations in the fuel level may be obtained by the use of thicker or thinner gaskets under the needle-valve seat.

VENTURI TUBE

The venturi tube has been referred to frequently throughout this discussion. Figure 40 shows a simple form of the

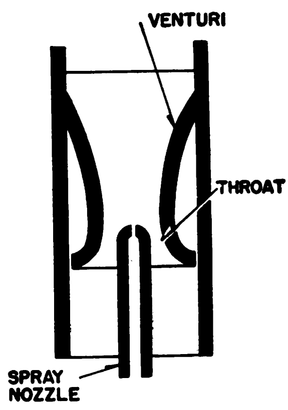

Figure 40.—Basic form of carburetor venturi tube.

venturi tube. It consists of a tube that tapers in from both ends to form a narrow section or throat. Air entering the bottom of the tube first passes through the rapidly narrowing part until it reaches the narrowest cross-section, or throat, and then passes through the gradually widening part to the discharge orifice at the upper end.

The principle of operation of the venturi tube is that a partial vacuum is formed in the tube at a point just above or beyond the throat. In figure 40, the flow of fluid through the tube from bottom to top results in the formation of a partial vacuum at the throat, and if a small hole were drilled into the venturi tube at this point, air would be drawn into the tube and the vacuum would be destroyed. In the case of a straight tube, no vacuum is formed, and the flow of air through it is not so rapid, as the pressure is practically constant at all points along the tube. In the venturi tube, the formation of the partial vacuum beyond the throat causes less resistance to the flow. Hence, the velocity of flow and the discharge are greater.

The formation of a partial vacuum at the throat of the venturi tube simply indicates that the pressure at that point is reduced until it is less than the pressure of the external atmosphere. The gasoline in the float chamber to which the spray nozzle is connected is acted on by atmospheric pressure, or about 15 p. s. i. at sea level, whereas the gasoline issuing from the spray orifice is subjected to a pressure that may be less by several p. s. i. As a result of this unbalanced condition of pressure, the gasoline is forced rapidly through the spray nozzle and is discharged from the nozzle orifice in the form of a spray. This spray is caught by the air stream and carried into the induction system. The reduction of pressure at the end of the spray nozzle also insures a more rapid vaporization of the fuel.

The temperature at which a liquid boils and changes into vapor is lowered by reducing the pressure on the liquid. Thus, water will boil at about 212° F. at sea level, but at the top of a mountain, 1 mile above sea level, where the pressure is less because the air is rarer, water will boil at about 202° F. Similarly, when the gasoline is discharged into the throat of the venturi tube, where the pressure is reduced, its boiling point is lowered considerably, and the result is that it vaporizes much more readily than when subjected to atmospheric pressure.

By the use of the venturi tube it is possible to speed up the

flow of air, and hence to increase the suction at the throat, or narrowest point, and at the same time to have relatively low suction existing in the manifold beyond the throat. The venturi tube is usually a detachable part of the carburetor barrel, as you will see in the part-sectional view of a typical air-bleed type carburetor in figure 41. In effect, it measures the amount of air admitted to the engine and is therefore made in different sizes, so that the proper size can be selected for the particular engine to which a carburetor is being fitted.

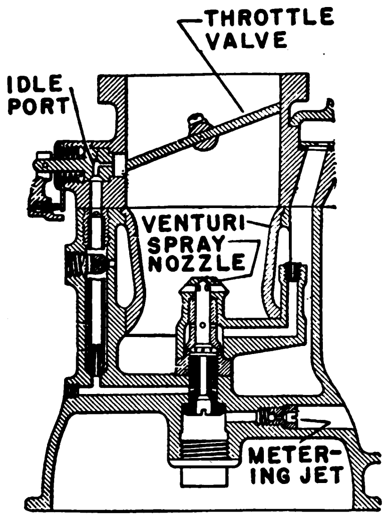

Figure 41.—Spray system of typical air-bleed carburetor.

The discharge nozzles of the carburetor are placed at the throat of the venturi, where the suction effect is the greatest. In some cases, two venturi tubes have been used, one within the other, with the nozzle at the throat of the inner tube. This creates high air velocity past the main-discharge jet, which is desirable to effect complete atomization of the fuel. A venturi is usually selected that will have an air velocity through the throat of about 300 feet per second at normal full-engine speed. As this will drop to zero when the engine is stopped, it is easily seen that a large range of air speed is available for adjusting the suction on the nozzles.

In some types of carburetors, holes are drilled radially through the venturi tube, producing a space with reduced pressure between the venturi and the carburetor barrel. This space of reduced pressure is used to control the effective pressure on the top of the fuel in the float chamber, as explained in connection with the float-chamber-suction system of mixture control. On some types of carburetors, the venturi is made a permanent nonremovable part of the barrel. A movable cone under the venturi, when raised, reduces the effective opening for a passage of air through the venturi. In other cases, the venturi itself is made variable, so that a mixture control is made possible by changing the location of the venturi throat in relation to the discharge nozzle.

DISCHARGE NOZZLES

The principal purpose of the discharge nozzle, figure 41, is to direct the fuel jet into the air stream passing through the venturi. The nozzle opening must be enough larger than the metering orifices used to measure the supply of fuel delivered to it, otherwise the nozzle itself will act as the metering device, and nullify the action of the metering jet. The nozzle body, stem, and base should be of streamline form to present as little resistance as possible to the flow of air through the carburetor. The shape of the mouth of the nozzle has considerable effect on the action of the carburetor.

A straight tubular nozzle with a sharp-edged opening is frequently used. Such a nozzle is easy to manufacture, and can be made in large quantities with unvarying characteristics. However, minute variations in the shape or size of the mouth of such a nozzle, or burrs in the edge of the opening, will produce considerable variation in engine service.

Stromberg airplane carburetors generally use a rose-type nozzle, so-called because of the shape of its head. The nozzle is provided with radial holes, drilled from the surface of the cone to the interior vertical fuel passage. Apparently the change of direction of the fuel emulsion flow from vertical to nearly horizontal just before it is delivered to the air stream, assists in mixing the fuel with the air.

As previously explained, it is common practice to have the idle mixture delivered to the carburetor barrel from a small port, or ports, uncovered by the edge of the butterfly throttle valve as it is opened. When the throttle valve is closed, the only passage for air through the carburetor is by way of the idle orifice leading around the edge of the valve. The demand of the cylinders will be such that the air cannot flow through this restricted passage fast enough to supply the demand, and consequently a high vacuum will exist above the throttle valve. The fuel discharge opening from the idle system is located at this orifice, where the velocity of flow is greatest.

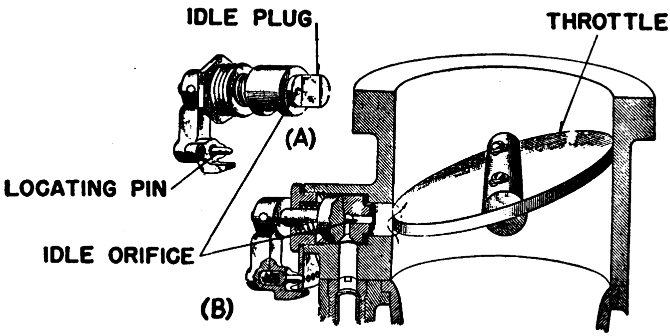

Figure 42.—Idle device used in Stromberg float-type carburetor.

As the throttle valve is opened to increase speed, a greater amount of air is permitted to flow past the valve and more fuel should be supplied to maintain the proper mixture ratio. However, the increasing supply of air tends to reduce the vacuum above the valve and hence the amount of fuel sucked from the discharge opening. Thus the mixture grows leaner as the throttle is opened until the idle system becomes of no importance in relation to the supply picked up from the main jets.

The idle orifice employed in Stromberg carburetors is contained in a plug, figure 42, view (*A*). The actual construction varies somewhat in different carburetor models. The

plug that contains the idle orifice is cylindrical, but is cut away at the end to form a semicylindrical projection. You will see in view (*B*) the end of the projection extends through the carburetor casting to the edge of the throttle valve.

With the jet in its normal position, figure 43, view (*A*), half of the open segment of the plug, view (*B*), is above the edge of the throttle valve, and the other half is below the edge. The upper end of the opening is in communication with the partial vacuum in the manifold above the throttle valve, and the lower end is open to the inside of the carburetor below the throttle valve. The suction in the manifold causes air from below the throttle valve to pass in through the open

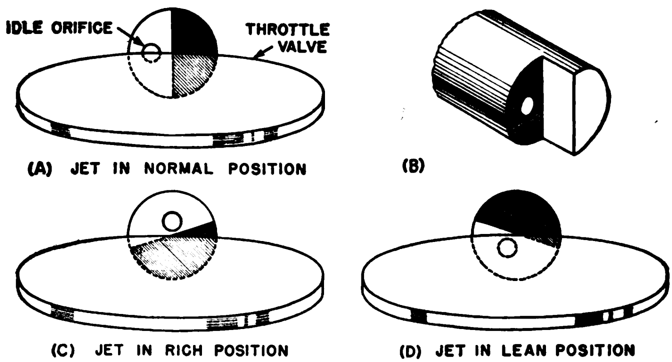

Figure 43.—Diagram showing action of idling device.

quarter-segment above the valve, as indicated by the curved arrow, figure 42, view (*B*). In passing through the bypass, air draws fuel from the idle orifice.

As the throttle is opened the area of the opening above the throttle valve is increased, and that below the valve is decreased, figure 43, view (*C*). As the amount of air flowing past the partly opened throttle has increased, the greater amount of fuel taken in through the upper opening is sufficient to form a combustible mixture necessary for the increased speed of the engine. The size and shape of the idle bypass can be adjusted by regulating the exposure of the

orifice by means of the edge of the throttle valve, so that a correct mixture is obtained for all idle speeds.

The mixture required for extremely low speeds is excessively rich, but as the idle speed is increased the mixture gradually is reduced to normal. The plug may be turned through a definite angle by means of the idle-control lever, which can be locked in different positions by a spring-loaded pin that fits into holes or notches in the quadrant. In this way the strength of the idle mixture may be controlled from the full-rich position, figure 43, view (*C*), to the full lean position, view (*D*), since turning the plug regulates the upper and lower positions of the openings, and consequently controls the ratio of gas to air to obtain the proper mixture.

The idle system of an airplane carburetor also maintains an air-bleed which serves the threefold purpose of reducing the suction on the idling metering orifice to controllable limits, providing a convenient means of mixture regulation, and of contributing to the operation of the system as a priming device.

As a priming device the idle passages are made considerably larger than is necessary to carry fuel only. The suction in them is reduced in normal running by the idling air-bleed. When the engine is at rest, the fuel rises to the float level both inside and outside the idle tube. This combined space is made equal to the volume of a rich fuel charge for one cylinder. In starting, if the throttle is left closed, the first quarter-turn of the engine will draw this rich charge into the intake manifold before the air-bleed through the idle system can begin. If the engine is allowed to remain still for a few seconds, the idle tube will again fill up to the float level, and another quarter-turn of the engine will draw in another rich charge, and so on. Thus, the carburetor can be made to prime the engine automatically for starting. If the engine is warm and this priming action is not desired, placing the throttle in the quarter-open position will reduce the manifold vacuum so that no priming action will take place as the propeller is turned.

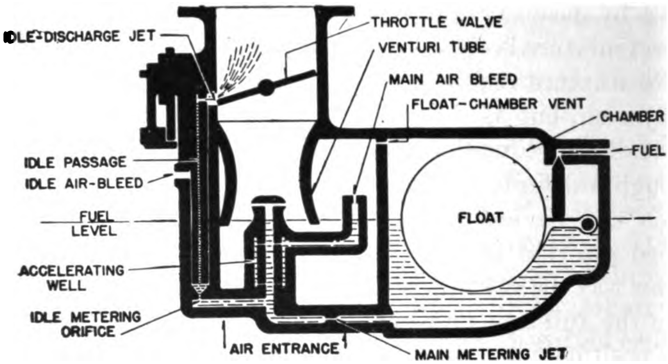

Figure 44.—Action of idle well in starting.

STROMBERG FLOAT-FEED CARBURETOR

You can see the action of the idle well in figure 44. Observe that the bottom end of the idle tube is immersed in fuel, and the tube therefore draws gasoline without air-bleed, giving a temporary rich mixture and automatic priming action. When the engine starts, the space around the idle tube is emptied, and the idle air-bleed begins to act. The engine then idles on a mixture of normal strength from the idle metering orifice, mixed with air coming into the bottom of the idling tube through the idle air-bleed.

In figure 45, the throttle is partly open to run the engine at a speed of between 900 and 1,000 r. p. m. The main-dis-

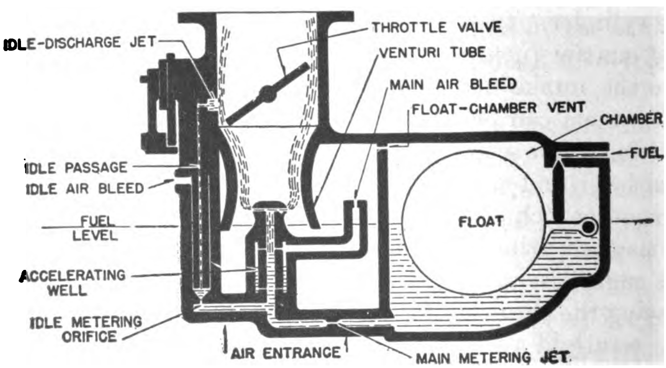

Figure 45.—Main discharge and idle discharge jets in operation.

charge jet and the idling-discharge jet are both in operation, as there is considerable suction at both places. You will notice also that the accelerating well is partly empty, the fuel level being below the point where the main air-bleed joins the acceleration well, so that an emulsion of fuel and air is formed in the fuel nozzle.

By referring to figure 46, you will see that, at full-open throttle, the idle-discharge jet has ceased to function and the main-discharge jet is supplying all the fuel. The well surrounding the main-jet passage has been completely emptied by the suction on the main-discharge nozzle, so that air is

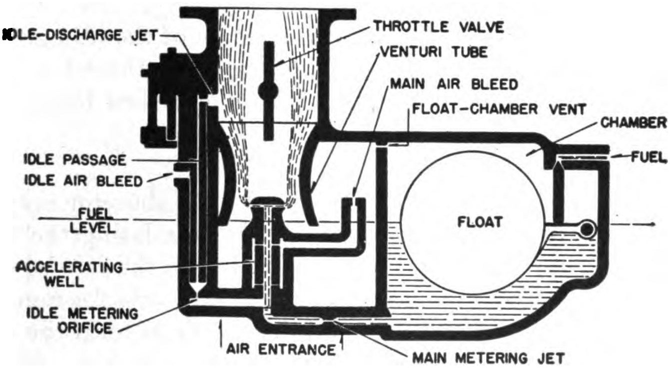

Figure 46.—Main discharge jet in operation, full-throttle opening.

being drawn through the air-bleed, down through the idling tube, through idling metering orifice, and into the base of the main-discharge nozzle. In this way, an emulsion is formed at the bottom of the main-discharge jet, and good atomization is obtained.

THROTTLE VALVE

A locomotive engineer sits in his cab with one hand constantly on the throttle lever. An automobile driver runs his car with his foot always on the accelerator pedal. An airplane pilot has many gages and operating gadgets that require constant attention, but the throttle is one thing that he always has under his immediate control. Why? Because the throttle valve controls the amount of fuel admitted to the

engine, and thus the power delivered by the engine, and its position must be varied to conform to the changing conditions under which the airplane is operating.

The throttle valve primarily used in carburetors is the butterfly type, illustrated in figure 42. This type of valve not only controls the engine throughout the power range, but serves a secondary purpose of regulating the idling mixture, as already described. For this reason it must be very closely adjusted. When two or more barrels of a carburetor are controlled they are usually synchronized—made to operate exactly in unison—by means of meshing gears carried on the ends of the throttle-valve shafts. The valves must be adjusted to work together, as the regulation of the idling mixture especially requires accurate closing of the throttles. The construction for accomplishing this is described later.

METERING ASSEMBLY

The metering assembly of an airplane carburetor may be said to include not only the orifice for regulating the flow of fuel to the discharge nozzles, but also, in the case of carburetors using the air-bleed principle, the orifices for regulating the admission of air to the fuel stream to form the fuel emulsion. From a theoretical consideration of the points involved, it would seem logical to require three metering orifices for the supply of fuel to an engine. These are for idling speeds, for mid-range speeds, and for flying speeds. Stromberg airplane carburetors do not employ a mid-range metering jet, but accomplish the same purpose by cutting in additional air-bleeds at high speeds. The main and idling air-bleeds of Stromberg carburetors are orifices similar to those used for metering the fuel, and are similarly changeable for necessary adjustments.

DESIGN OF JETS

In figure 47 you are shown a sectional view of the type of metering jets used in Stromberg carburetors. These jets are machined very accurately. The smallest opening is the measuring orifice, and it is placed in the middle of the jet

where it is well protected. Never use wire or other metal devices to clean out the passage through the jet, as even slight scoring or abrasion will alter the amount of fuel passed by the jet. Jets are sized and numbered according to the twist drill and wire-cage standard, and are usually manufactured of brass. The scouring action of the fuel in passing through the jets will in time enlarge the bore and necessitate replacing the jets.

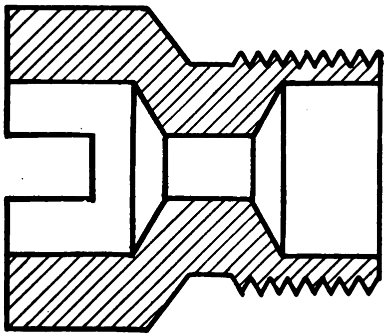

Figure 47.—Metering jet used in Stromberg carburetors.

The metering system in general must provide a proper fuel supply to the engine at all speeds from the lowest to the highest. For the sake of good acceleration, or passing from one speed to another, it must be arranged so that the action of one metering jet will merge smoothly into that of the next in order to provide for smooth operation of the engine while running on any one jet, or on any combination of jets. Even the best designs may fail to achieve this result, and the engine may fire somewhat irregularly while shifting from one jet to another.

TEAM WORK

Sports history bristles with the names of great combinations that achieved fame, not because of any individual greatness that they displayed, but because as a unit they were almost unbeatable.

But team work, or coordination, is not limited to sports. It is just as important in other things. It is important

in the airplane engine and in the carburetor. All of the detailed parts of the carburetor so far described have their individual functions and are complete in themselves, but they are of little value to the airplane until they are merged into a single harmonious whole. For this reason it's a good idea to consider the function of the various parts of a simple carburetor in relation to each other, before taking up individual types of carburetors, in order that the actual operation may be better understood.

Fuel enters the carburetor at the inlet, passes through the fuel strainer, enters the float chamber past the needle valve, and is shut off by the rising of the float. From the float chamber, the fuel passes through the main-metering jet, and rises in the central passage of the main-discharge nozzle. It then passes through the idling-metering jet to the idling well and the space surrounding it, until the fuel level throughout the carburetor is the same as that in the float chamber. The main-discharge nozzle surrounds the central stud and thereby provides a space between the two, called the accelerating well. The main-discharge nozzle also carries the discharge orifices at its upper end and the main air-bleed at one side. The main air-bleed opens into the space behind the venturi, which space is in communication with the air intake of the carburetor and therefore is at atmospheric pressure. The main-discharge nozzle central stud is provided with air-bleed holes at two levels in the accelerating well, and also with holes leading to a passage that connects to the idling system.

When the engine is turned over with the throttle closed, the partial vacuum above the throttle causes fuel to be sucked up the idle tube. As this suction in starting draws the fuel up the idle tube faster than it can come in through the idle-metering jet, the level in the space surrounding the idling tube is lowered by pulling the fuel into the tube through the holes near its lower end. The space around the idling tube is thus a small accelerating well for the idle system, which is itself really a small carburetor.

The capacity of the space around the idle tube is made sufficiently large to give a good charge to one cylinder, so that in effect this part of the system is a priming device. If the engine is turned over sufficiently to draw a charge into one cylinder and then allowed to rest a moment, the idle system will refill with fuel through the idle-metering jet and another cylinder can be primed, thus giving each cylinder in turn a good starting charge.

Very little air will flow through the venturi when the engine is turned over with a closed throttle, but the flow past the idle orifice will be fast enough to pull fuel from the idle tube. The action of the idle jet has already been explained in detail. As the fuel level in the space surrounding the idle tube is lowered to the holes at the bottom of that tube, the idle air-bleed begins to bleed air into the fuel, causing an emulsion and air bubbles. To better show the construction of the idle air-bleed, the idle tube does not appear on the illustrations, figures 44, 45, and 46.

You must understand that air enters the idle air-bleed at atmospheric pressure from the space behind the venturi, and is discharged into the upper part of the space surrounding the idle tube by means of the T-shaped passages in the idle air-bleed, as shown. The air then travels down to the bottom of the space until it can enter the idle tube through the small holes just above the idle-metering jet. The idle tube is continuous from these holes to the point where it enters the discharge jet, and in the actual instrument is not broken at the idle air-bleed.

The idle orifice is semicircular and is arranged so that the area of the orifice above or below the edge of the throttle valve can be regulated by moving the plug crank, as previously explained. The idle-discharge jet is held in place by the coiled spring and plug shown in the illustration. The spring is necessary to prevent any leakage of fuel into the discharge orifice around the sides of the jet instead of through the passage provided. A small sector with holes is fixed behind the idle-plug crank, and a spring-actuated pin in the crank may be set in any of the holes, thus holding the crank

in any desired position. A mixture control is of the float-chamber-suction type previously described. The actual carburetor differs from that shown in having an air horn attached to the air intake, and a drain connection at the lowest part of the intake opening to provide for drainage of excess fuel that may collect there.

QUIZ

1. (a) What device controls the quantity of mixture that passes to the engine cylinder?
   (b) Is the fuel supply entirely shut off from the engine when this device is in a closed position? Explain your answer.
2. Which of the systems in the carburetor sometimes operates as a priming device?
3. (a) What is the fundamental difference between updraft and downdraft carburetors?
   (b) Which is located relatively higher on the engine?
4. Why won't the engine run when the mixture-control valve is in the idling cut-off position?
5. (a) What is the principal purpose of the discharge spray nozzle?
   (b) Into what part of the carburetor does it open?
   (c) How does pressure in this area compare with atmospheric pressure?
   (d) What effect does this have on the vaporization of gasoline discharged from the spray nozzle? Why?
6. How are the discharge nozzles usually located in a duplex carburetor in relation to the float chamber? Why?
7. How is the rose-type nozzle designed to assist in mixing the fuel with the air?
8. The Stromberg carburetor operates on the ____________ system.
9. The device for enabling the pilot to vary the quality of the mixture is called the ____________.
10. The two different ceilings for aircraft are the ____________ and the ____________.
11. In the float-type carburetor the fuel should be subjected to no other force than the action resulting from the ____________.
12. The reduction of pressure at the end of the spray nozzle in the venturi tube insures a ____________ of the fuel.
13. The throttle valve, primarily used in carburetors, is the __________ type.
14. How are jet openings sized?
15. The idle-discharge jet is held in place by a coiled spring and plug. The spring is necessary to prevent ____________ into the discharge orifice.

CHAPTER 7

STROMBERG FLOAT-TYPE CARBURETORS

MODEL DESIGNATION

Stromberg airplane carburetors are made in a variety of models to meet special requirements, and are designated by a series of letters and numbers, the first two being NA—natural atomization—in all cases of float-type carburetors.

Following the general model designation NA in float-type carburetors, appears a hyphen, and then follows a letter designating the style of carburetor, such as S for single vertical; U for double barrel, with a single float between the barrels; D for double-barrel, with a single float in the rear; DD for double-barrel downdraft, with a single float to one side; Y for double-barrel, with a Y-type double-float mechanism, double-float chamber and a single needle valve; T for a triple-barrel, with double-float chamber; F for four barrels, with two independent floats and needles; and R for a rectangular barrel.

The number following the model and style letters indicates the rated size of the carburetor. Since the rated size is $\frac{3}{16}$ inch smaller than the actual diameter of the carburetor barrel, the number 1, for instance, following the letter indicates a carburetor with a $1\frac{3}{16}$-inch barrel. Each unit increase in the size number indicates an increase of $\frac{1}{4}$ inch in the carburetor barrel. For example—No. 2 size is actually $1\frac{3}{16}+\frac{1}{4}=1\frac{7}{16}$ inches in diameter, and No. 3 size is $1\frac{3}{16}+\frac{1}{4}+\frac{1}{4}=1\frac{11}{16}$ inches in diameter.

A model modification letter following the size number indicates a MAJOR design change distinguishing a new model from preceding ones. A number designation following the model modification letter indicates a MINOR modification in design.

For example, NA–R9C2 may be broken down as follows: NA, type; R, rectangular barrel; 9, size of carburetor; C, major design change; and 2, minor modification in design.

This model designation appears on the manufacturer's nameplate with the serial number and is attached to the carburetor.

Several different models of float-type carburetors have been used in Navy airplanes, and it is obviously impracticable to attempt to describe them all here. Consequently, two models in active use, and which may be considered representative of modern construction, will be discussed. These are the NA–R9B and the NA–R9C2. Both are single-barrel updraft carburetors with a single hinge-type float. In mounting either type carburetor on the engine, the float chamber is placed at the side with the fuel inlet to the rear. The needle valve requires a fuel pressure of 3 p. s. i. or a gravity-feed system having a minimum fuel head of 97 inches. The throttle lever has a 70-degree travel and requires a control-rod movement of $2^{19}/_{64}$ inches on the NA–R9C2 and $2^{9}/_{32}$ inches on the NA–R9B carburetor. A $\frac{1}{2}$ x $\frac{3}{8}$-inch reducing bushing is supplied with NA–R9C2 carburetors at the factory, but, when possible, the manufacturers recommend that the $\frac{1}{2}$-inch inlet be used.

MODEL NA–R9B

This carburetor is designed with a needle-type, hand-operated, mixture control, and needle-type, throttle-shaft operated economizer.

In figure 48, a top view is shown—usually known as a plan elevation—and in figure 49, a front view—or front elevation—of the Stromberg NA–R9B carburetor. These views will help you to identify some parts of the carburetor and to distinguish this model from others when you come in contact with it. Sectional views are shown to bring out the details of construction. To simplify the description of the various views of the carburetor, the same reference numbers have been given to like parts in all views. If a certain part doesn't appear to be as clear as you would like in one

illustration, look for the same part in another view. It will have the same identifying number in each case.

The main body of the carburetor is fastened to the throttle body by screws. The fuel enters the main body through the fuel inlet and flows through a filter screen in the housing directly below the inlet, before passing into the float chamber of the carburetor. The mixture-control lever is used to control the mixture of fuel and air by regulating the flow of fuel to the main-metering system of the carburetor. The idle-adjusting lever moves over a quadrant, and regulates the discharge of the idle tube contained in the vertical housing below the lever, figure 49. This view also shows the accelerating pump, the main air-bleed, and the idle air-bleed. The main-jet plug is removed when it is desired to clean out the main jet. Cleanout plugs are provided for the metering and fuel passages in the body of the carburetor.

It is advisable to fix these points in your mind, as it is necessary to keep the various parts clean in order that the carburetor will operate at highest efficiency. Also shown at the bottom of the carburetor are the drain plug for the float chamber and the plug that holds the filter element of the fuel strainer in place. A screw at the lefthand end (fig. 49) is provided to adjust the fulcrum of the float lever in the float chamber.

In the top view (fig. 48) the throttle valve is shown carried on the throttle shaft, on one end of which is mounted the throttle operating lever and on the other end the lever that operates the accelerating pump. Another arm on the throttle shaft operates the economizer.

The sectional view shown in figure 38 is that of the NA–R9B carburetor taken through the line *A–A*, figure 48.

Fuel enters the carburetor at the inlet and after passing through the strainer flows through the fuel passage to the float chamber. A constant-fuel lever is maintained in the float chamber by a needle valve operated by a float, which is made with a flat top so as to reduce the overall height of the carburetor. The float chamber is vented through the opening in the top. In this illustration, is shown also the

throttle-valve shaft on which are keyed the arm that actuates the accelerator pump through a lever, and the arm that operates the economizer needle valve.

The path of the fuel on leaving the fuel chamber can be seen in figure 50, which represents a sectional view of the carburetor taken at *C–C*, figure 48. From the float chamber, the fuel flows past the mixture-control needle valve and the main-metering jet into a passage leading to the main-discharge nozzle, which is screwed into a boss projecting into the air intake of the carburetor, and is located centrally in the venturi tube. The fuel is discharged from the end of the nozzle through several small passages that end in a groove around the nozzle.

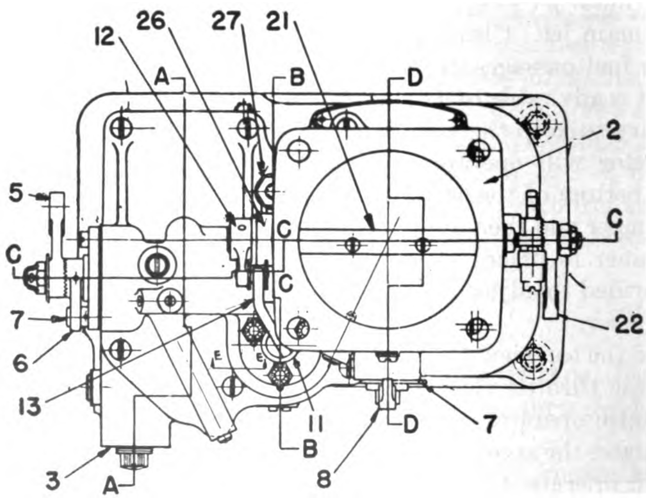

Figure 48.—Top, or plan, view of Stromberg NA–R9B carburetor.

In its passage through the main-discharge nozzle the fuel is mixed with air from the main air-bleed which in turn obtains its air from behind the main venturi through the passage into which the air-bleed extends. The air is bled into the air stream through holes in the main-discharge nozzle, and helps to atomize the fuel. The actual metering of the fuel is done by the main jet.

MANUAL MIXTURE CONTROL

The amount of fuel permitted to leave the float chamber is regulated by a needle-type control valve, which is located directly above the main-metering jet. This valve is operated

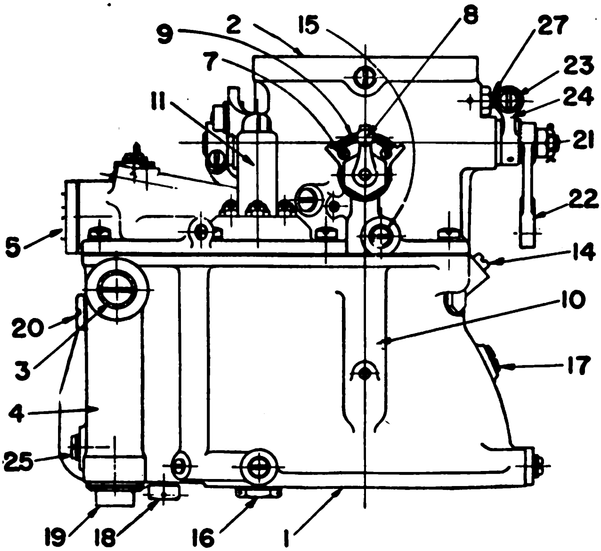

Figure 49.—Front view of NA–R9B carburetor

PARTS SHOWN IN FIGURES 48 AND 49

1. Main carburetor body.
2. Throttle body.
3. Fuel inlet.
4. Screen housing.
5. Mixture-control lever.
6. Mixture-control lever stop arm.
7. Mixture-control lever stop.
8. Idle adjusting lever.
9. Idle adjusting-lever quadrant.
10. Idle-tube housing.
11. Accelerator pump.
12. Accelerator-pump arm.
13. Accelerator-pump lever.
14. Main air-bleed.
15. Idle air-bleed.
16. Metering-jet cleanout plug.
17. Main-jet cleanout plug.
18. Float-chamber drain plug.
19. Strainer plug.
20. Float-lever fulcrum adjusting plug.
21. Throttle-valve shaft.
22. Throttle lever.
23. Throttle-stop screw.
24. Throttle-lever stop.
25. Fuel-passage cleanout plug.
26. Economizer arm.
27. Economizer.

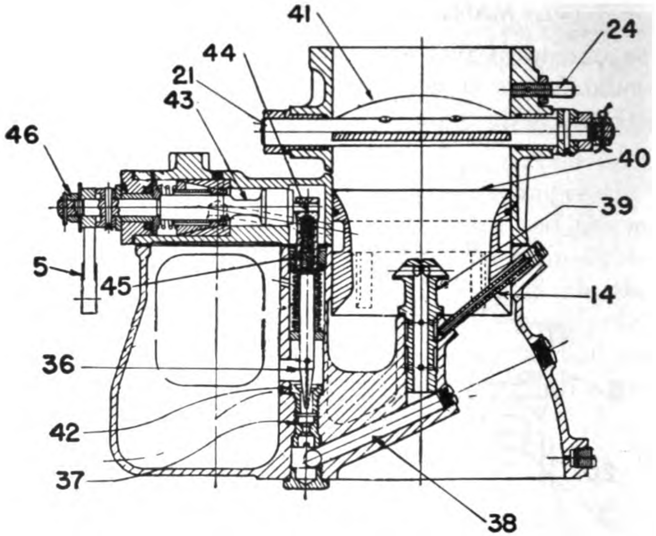

Figure 50.—Section of Stromberg NA–R9B carburetor taken on line C–C figure 48.

PARTS SHOWN IN FIGURE 50

36. Mixture-control needle valve.
37. Main metering jet.
38. Fuel passage to discharge nozzle.
39. Main-discharge nozzle.
40. Venturi tube.
41. Throttle valve.
21. Throttle shaft.
14. Main air-bleed.
42. Mixture-control valve seat.
43. Mixture-control shaft.
44. Mixture-control pin.
45. Mixture-control valve stem.
5. Mixture-control lever.
46. Mixture-control stop arm.
24. Throttle-lever stop.

by a pin mounted off center—or eccentrically—on the mixture-control shaft, and engages the upper end of the control-valve stem. At its outer end the control shaft carries a lever which is connected by a rod to the dash of the airplane. When the shaft is turned so as to produce a leaner mixture, the needle valve is lowered to its seat, thereby restricting the flow of fuel to the main-metering jet.

When the control lever is moved to a richer position, the needle valve is raised from its seat, and more fuel is admitted to the main-metering jet. A stoparm is keyed on the control

shaft directly beneath the control lever and its motion is limited by a stop, thereby preventing the rotation of the control shaft beyond the full-rich position. The stoparm and stop are shown in figure 48. An adjusting screw limits the rotation of the throttle shaft by striking a stop, so as to obtain the most desirable idling speed.

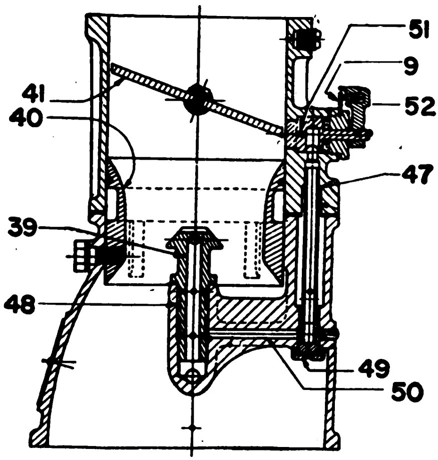

Figure 51.—Idling system of Stromberg NA–R9B carburetor, section through D–D, figure 48.

PARTS SHOWN IN FIGURE 51

47. Idle tube.
48. Space around main-discharge nozzle.
49. Idle-tube holder.
50. Horizontal fuel passage.
41. Throttle valve.
51. Idle-discharge jet.
52. Idle-discharge adjusting lever.
9. Adjusting-lever quadrant.
39. Main-discharge nozzle.
40. Venturi tube.

PRIMING SYSTEM

The primary system in the carburetor consists of a valve on the mixture-control stem, and passages arranged so that fuel from the accelerating pump passes through the valve to the pump-discharge nozzle in the carburetor barrel when the mixture-control lever is in the full-rich position. Or it passes through the valve to a ⅛-inch pipe tap connection for the engine-primer system when the control lever is in the full-

lean position. The point at which the fuel enters the priming system is about 55 degrees from the full-rich position.

IDLE SYSTEM

The idling system, which acts at speeds below which the main-metering system does not operate, is shown in figure 51, which is a section through the line *D–D*, figure 48. The idle tube draws fuel from a space around the main-discharge nozzle which communicates with the control fuel passage in the nozzle. The fuel flows through the horizontal idle tube, passing through an idle-metering orifice that is drilled through the wall of the idle-tube holder in line with the horizontal fuel passage.

The mixture is discharged from the idle tube into the carburetor barrel directly above the throttle valve, which is almost in the closed position. The idle system operates up to an engine speed of 900 to 1,000 r. p. m. The discharge from the idle tube is regulated by turning the idle-discharge jet by means of the adjusting lever, which moves over a quadrant—a metal piece forming a quarter of a circle. The quadrant holds the adjusting lever in any desired position.

ECONOMIZER

In figure 52, a section of the carburetor is taken through the line *B–B*, figure 48. This view illustrates the economizer and accelerator-pump. The economizer acts as an enriching device that provides a rich mixture at full throttle for greatest power, and a leaner mixture at cruising speeds for greatest economy. The economizer consists of a needle valve and seat, located in a passage between the main-discharge nozzle and the float chamber. The needle valve is held in its seat by a spring at idling, taxiing, and cruising speeds, so that no fuel can flow from the float chamber past the needle-valve seat into the metering jet below the seat. When an engine with a fixed-pitch propeller is running at a speed of about 200 r. p. m. below full-throttle speed, a lever arm fastened on the throttle shaft—shown in section—engages a nut on the

economizer needle-valve stem and raises the needle valve off its seat. The lever arm is shown in figure 48.

The raising of the needle valve allows fuel to flow past the valve and through the metering jet into a passage below the jet which communicates with the main-discharge nozzle. The position of the nut on the upper end of the needle-valve stem, determines the engine speed—that is, the position of the

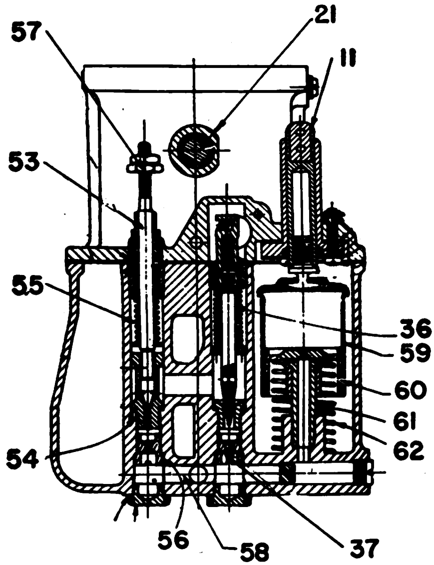

Figure 52.—Economizer and accelerator pump used on Stromberg float-type carburetors.

PARTS SHOWN IN FIGURE 52

53. Economizer-needle valve.
54. Economizer needle-valve seat.
55. Economizer needle-valve spring.
56. Economizer-metering jet.
21. Throttle-valve shaft.
57. Economizer-adjusting nut.
58. Economizer-fuel passage.
11. Accelerator pump.
59. Accelerator-pump sleeve.
60. Accelerator-pump piston.
61. Accelerator mushroom valve.
62. Accelerator piston spring.
36 Mixture-control needle valve.
37. Main-metering jet.

throttle valve at which the needle valve is lifted off its seat. It is therefore important that this nut be adjusted correctly in order that the engine will not be operating on too lean a mixture at cruising speeds. The economizer-metering jet, as well as the main-metering jet, is of the fixed-opening type. The size of the jets is determined by tests so that no adjustment for different operating speeds is required.

ACCELERATOR PUMP

The accelerator pump shown in figure 52 provides a smooth and quick acceleration of the engine by supplying a quantity of fuel in addition to that supplied by the regular metering system when the throttle is opened quickly. The pump is operated from the throttle valve through an arm and a lever as shown in figure 49. Going back to figure 52, the pump itself consists principally of an inverted cylinder, or sleeve, which, through the action of the arm and lever, is pressed down as the throttle valve is opened. The sleeve slides over a piston which in turn slides freely on a mushroom-type valve.

Fuel from the float chamber enters the space above the piston through the clearance space between the piston and the sleeve. When the throttle is closed, or is in any set position, the piston is held at the top of the valve by a spring, thereby closing off several holes drilled in the valve wall, and communicating with a central tube in the valve. However, when the throttle is opened suddenly, and the pump sleeve is pressed down, the piston is forced down by the pressure of the fuel above it, thereby exposing the holes in the valve wall and allowing gasoline to enter the tube at the center of the valve. From the tube the fuel flows through the passage at the bottom of the carburetor to the main-discharge nozzle. The illustration also shows the mixture-control needle valve and the main-metering jet.

STROMBERG NA–R9C2 CARBURETOR

The Stromberg NA–R9C2 float-type carburetor follows the general design of the NA–R9B model just described, but

is built with a MANUAL AND AUTOMATIC BACK-SUCTION TYPE OF MIXTURE CONTROL, and a VENTURI SUCTION-OPERATED ECONOMIZER. It is also equipped with a cruise valve that allows a manual selection of a lean economical mixture for cruising, or a rich mixture for maneuvering and climbing, with the same cruising throttle opening. Both models employ built-in primers, but the primer used on the NA–R9C2 model operates on a different principle from that described in connection with the NA–R9B carburetor.

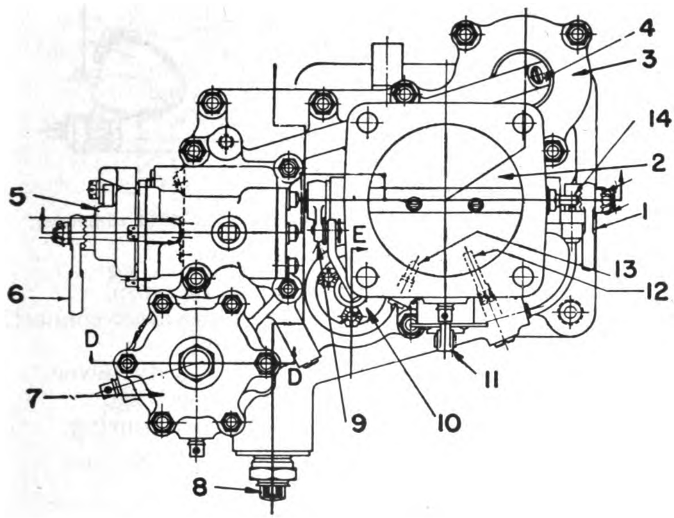

Figure 53.—Top, or plan, view of Stromberg NA–R9C2 carburetor.

PARTS SHOWN IN FIGURE 53

1. Throttle lever.
5. Manual mixture-control cover.
6. Manual mixture-control lever.
8. Fuel-inlet plug.
9. Accelerator-pump lever.
11. Idling-adjusting lever.
14. Throttle stop.
15. Cruise-valve connecting link.
16. Cruise-valve lever.
17. Strainer plug.
18. Strainer housing.
19. Idling tube.

The float mechanism, main-metering system, and idle system of the NA–R9C2 model are the same as described for the NA–R9B model, being characteristic of Stromberg float-feed carburetors, and the description of these parts will not be

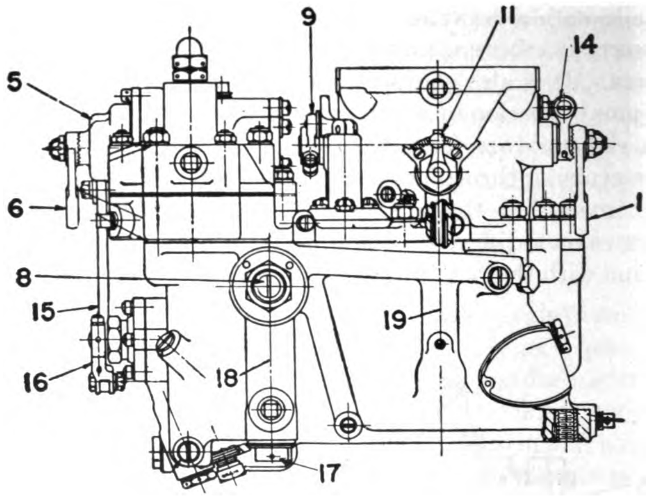

Figure 54.—External front view of Stromberg NA–R9C2 carburetor.

PARTS SHOWN IN FIGURE 54

1. Throttle lever.
5. Manual mixture-control cover.
6. Manual mixture-control lever.
8. Fuel-inlet plug.
9. Accelerator-pump lever.
11. Idling-adjusting lever.
14. Throttle stop.
15. Cruise-valve connecting link.
16. Cruise-valve lever.
17. Strainer plug.
18. Strainer housing.
19. Idling tube.

repeated. However, the two models differ quite radically in their outward appearance, and for this reason the top or plan view and the front view of the NA–R9C2, shown in figures 53 and 54, respectively, will assist you in recognizing this model.

ECONOMIZER METERING SYSTEM

The economizer system, which you can see in the sectional diagram in figure 55, is, in reality, an enriching device operated by the suction in the venturi tube. It provides a rich mixture at high-power output, and permits a leaner mixture at cruising power for maximum economy. The economizer consists of a needle valve and its seat, located in a passage between the main-discharge nozzle and the float chamber.

The needle valve is suspended from a diaphragm, the other side of which is connected through a passage to a suction nozzle extending into the venturi tube.

As the throttle valve is opened, the suction in the venturi increases. When it reaches the point for which the economizer-valve spring is set, the needle starts to open, allow-

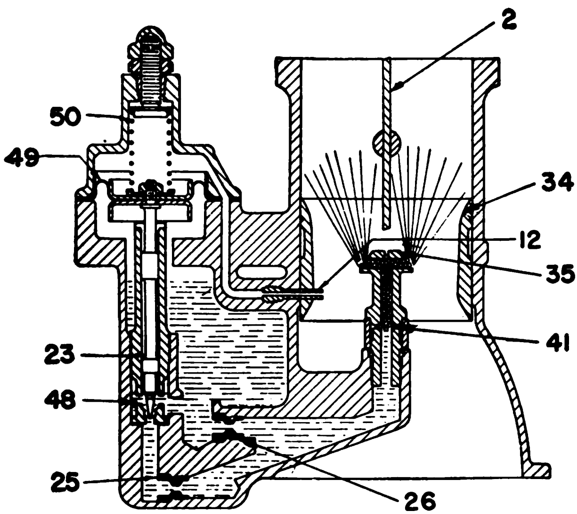

Figure 55.—Diagram of Stromberg vacuum economizer system.

PARTS SHOWN IN FIGURE 55

26. Main-metering jet.
23. Economizer needle valve.
25. Economizer metering jet.
34. Venturi tube.
35. Main-discharge nozzle.
2. Throttle valve.
41. Main air-bleed holes.
12. Economizer suction nozzle.
48. Economizer needle-valve seat.
49. Economizer diaphragm.
50. Economizer spring.

ing fuel to be drawn past the needle-valve seat and the economizer jet into the main-metering system, and enriches the mixture. When the throttle starts to close, a point is reached where the tension of the economizer spring is greater than the suction pull of the venturi. The needle valve then drops and closes the economizer passage.

MIXTURE-CONTROL SYSTEM

The NA–R9C2 carburetor is equipped with a back-suction type mixture-control system. In this system, as was ex-

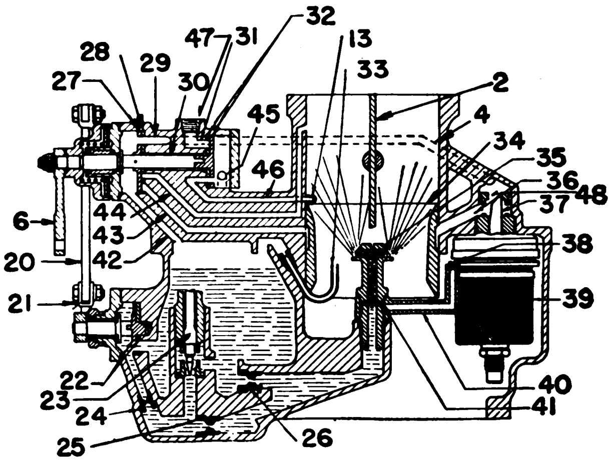

Figure 56.—Diagram of mixture control and cruise valve, Stromberg carburetor NA–R9C2.

PARTS SHOWN IN FIGURE 56

2. Throttle valve.
4. Automatic mixture-control passage.
6. Manual mixture-control lever.
13. Accelerating-pump discharge nozzle.
20. Cruise-valve connecting link.
21. Cruise-valve lever.
22. Cruise-valve plates.
23. Economizer needle valve.
24. Cruise-valve metering jet.
25. Economizer-metering jet.
26. Main-metering jet.
27. Mixture-control plate—movable.
28. Mixture-control plate—fixed.
29. Automatic mixture-control passage.
30. Mixture-control shaft extension.
31. Priming-valve passage.
32. Primer valves.
33. Mixture-control suction nozzle.
34. Venturitube.
35. Main-discharge nozzle.
36. Automatic mixture-control passage to vent hole behind venturi.
37. Automatic mixture-control needle.
38. Main air-bleeder.
39. Automatic mixture control.
40. Main air-bleed arm.
41. Main air-bleed holes.
42. Mixture-control passage.
43. Mixture-control passage.
44. Idle cut-off passage.
45. Primer channel.
46. Auxiliary-pump discharge passage.
47. Pipe connection for primer.
48. Automatic-control needle orifice.

plained previously, the suction existing in the venturi is utilized to decrease the fuel flow at altitude by applying a part of the suction on the top of the fuel in the float chamber to counteract the suction of the venturi on the main-discharge

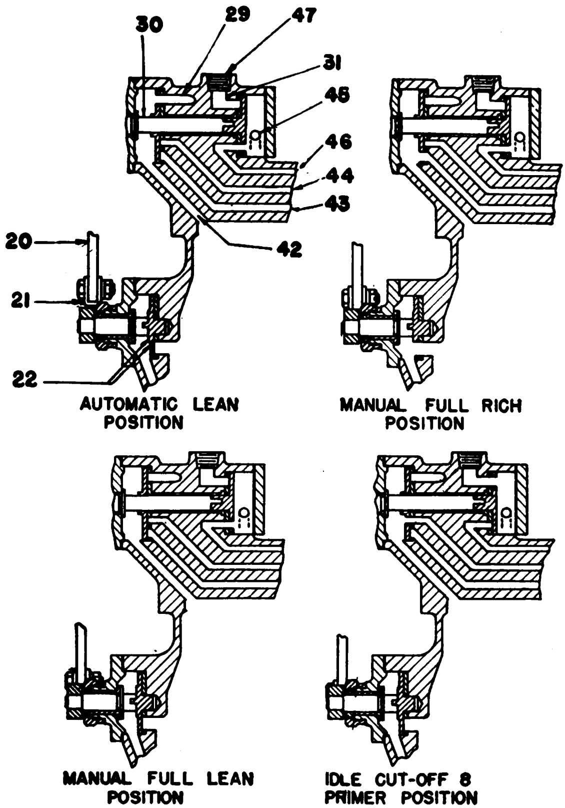

Figure 57.—Mixture-control and cruise-valve position.

PARTS SHOWN IN FIGURE 57

20. Cruise-valve connecting link.
21. Cruise-valve lever.
22. Cruise-valve plates.
29. Automatic mixture-control passage No. 1.
30. Mixture-control shaft extension.
31. Priming-valve passage.
42. Mixture-control passage.
43. Mixture-control passage.
44. Idle cut-off passage.
45. Primer channel.
46. Auxiliary-pump discharge passage.
47. Pipe connection for primer.

nozzle. The MANUAL-CONTROL SYSTEM, figure 56, consists of the operating lever; two valve plates, one of which is fastened in the body and the other is free to move; a suction nozzle that extends into the venturi, and has its open end at approximately the same height as the main-discharge nozzle; and the necessary connection passages.

When the manual-control lever is in the full-rich position the slots in the two plates line up, allowing air to flow from the vent space between the venturi tube and in the carburetor barrel through the mixture-control passage No. 3, and the mating holes in the plates, into the channel No. 2, and thence out through the suction nozzle—see the detail of the mixture control in figure 57.

As the control level is moved from the full-rich to the lean position, it moves the one plate around with it, and gradually closes the mating opening in the two plates. The flow of air from the vent space around the venturi is thereby restricted, and the top of the float chamber approaches an air-tight condition. Consequently, as fuel leaves the float chamber, a vacuum—or suction—is produced in the top and the fuel flow is reduced.

The automatic mixture-control unit comes into operation when the manual control is placed in the automatic position.

The construction of the AUTOMATIC-CONTROL unit is shown more clearly in the enlarged sectional view, figure 58. Refer to both this illustration and figure 56 while reading the explanation of the operation of this device. The unit consists of a tapered needle that is operated by a sealed bellows. The functioning of the bellows depends upon the density of the air entering the carburetor, which varies with temperature as well as pressure. The bellows is filled with nitrogen which responds to changes in temperature and pressure of the air, and oil which serves to dampen the tendency of the flexible metallic bellows to vibrate. As the density of the air changes, the bellows expands or contracts, and moves the tapered needle in its seat. This changes the size of the orifice into which the tapered needle extends, and thus controls the suction above the fuel in the float chamber.

The suction in turn controls the rate of fuel flow from the main-discharge nozzle.

The atmosphere vent controlled by the automatic-mixing valve is through the inclined passage No. 2, figure 56, through the mating openings in the two valve plates and a passage—referred to as the automatic mixture-control passage in the illustration—the opening between the control-valve needle and its seat, and the inclined passage at the left of the control needle, which terminates in the space around the outside of the venturi tube. When the bellows expands it raises the needle valve and moves the tapered portion farther into

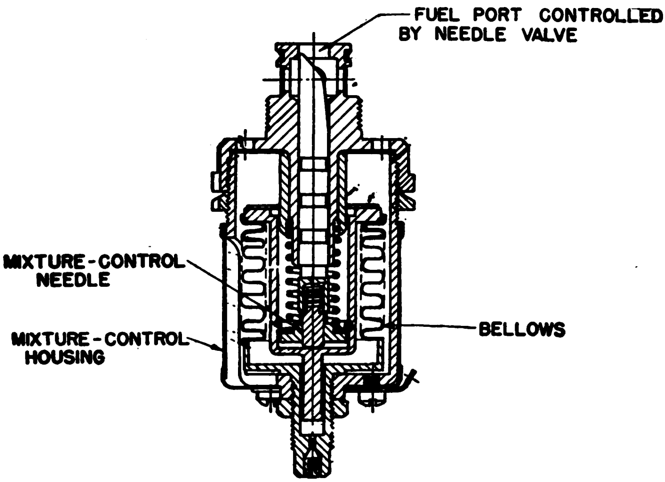

Figure 58.—Automatic mixture-control unit.

its seat, thus restricting the air passing from the air space back of the venturi, and bringing about a reduction in the pressure on the fuel in the float chamber.

IDLE CUT-OFF

The idle cut-off as used on the NA–R9C2 carburetor is a part of the mixture-control system. When the control lever is placed in the idle cut-off position, holes in the two mixture-control plates, figure 56, line up so that the high suction existing above the throttle acts directly on top of the

fuel in the float chamber by means of the idle cut-off passage. You will observe in the illustration that the idle cut-off passage leads from the holes in the plates to a point above the throttle-valve shaft. When the throttle valve is closed, the suction on the float chamber stops the flow of fuel through the idle-discharge nozzle and the engine will cease firing.

CRUISE VALVE

In figures 56 and 57, you will see a cruise valve operated by a link connected to an arm on the mixture-control shaft. This valve allows a selection of a lean mixture for maximum economy for cruising, and a richer mixture for climbing and maneuvering. The cruise valve consists of two plates, similar to those used in the mixture-control, and a metering jet. As you will see in either illustration the cruise-valve unit is located directly below the mixture control, and is connected in such a way that, when the mixture-control is in any position except the automatic-lean position, the holes in the cruise-valve plates line up.

In this position, fuel flows from the float chamber through the cruise-valve metering jet, and then out of the main-discharge nozzle. A richer mixture is thus created for maneuvering and climbing. With the mixture-control in the automatic-lean position, the hole through the cruise-valve plates is closed, and a leaner mixture is obtained for economical cruising power. This is the position shown in figure 49, view (*A*).

PRIMER SYSTEM

There is still another device shown in figures 56 and 57, the primer system. This system is also tied in with the mixture-control system, as it is operated by an extension of the control shaft. When the mixture-control lever is in the primer position, the primer valve opens the priming-valve passage 31, so that fuel from the channel 45, which was discharged by the accelerating pump, will go out of the tapped opening on the top of the mixture-control housing. In all other positions of the priming valve, the fuel is discharged

through the accelerator-pump discharge passage 46 to the nozzle 13 in the carburetor barrel.

ACCELERATOR SYSTEM

The accelerator system is of the same construction as described in connection with the NA–R9B carburetor. The accelerator discharge nozzle of the Model NA–R9C2 is visible in figure 53.

GENERAL SERVICE SUGGESTIONS

After installing a float-type carburetor in an engine, be sure that the throttle and mixture-control levers are connected properly and that they have no appreciable play—or backlash. Then check the levers with the dash controls to see whether they have a full movement in the proper direction. Both levers may be swung around relative to their shafts so that they may be adapted to any installation.

After the carburetor and operating mechanism are installed properly, check the carburetor and all fuel lines attached to it for leaks at the required operation pressure, and check all parts for tightness and safetying before starting the engine.

PRIMING

The procedure for starting the engine depends on the priming equipment and the starting system furnished by the engine manufacturer. At the present time, there are two distinct types of priming equipment in use, namely, the displacement plunger-type primer, which is a unit in itself, and the type of primer that is built into the carburetor. With the displacement type of primer, prime the engine by first turning the fuel on, and pushing in the plunger of the primer slowly until the fuel pressure registers 3 pounds. Pull the plunger out slowly to insure that the primer will be completely filled with fuel, and then push it in again rapidy so that the fuel will be forced through the priming orifices in the cylinder in the form of a spray.

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To operate a primer that is built into the carburetor, place the mixture-control lever against the stop in the priming position, with the fuel turned on, and the carburetor float chamber full of fuel. Then pump with the auxiliary fuel pump, if necessary, to fill the float chamber and slowly operate the throttle valve. Place the mixture-control in the full-rich or automatic-rich position before attempting to start the engine. Experience with each individual engine will show you how much priming is required for different atmospheric conditions.

In general, remember that the engine should be primed by the system designed for that purpose, and overpriming should be avoided. Avoid rapid working of the throttle, as this will cause a large amount of gasoline to be discharged into the intake system. If the engine should fail to start immediately the gasoline would run down into the air scoop of an updraft type of carburetor, and, in case of a backfire, might cause a dangerous fire. With the downdraft type of carburetor, the gasoline will run down into the induction system and either flood the engine and cause scored cylinders, as a result of washing the lubricant from the wall of the cylinders. Or, it will run through the supercharger drain tube and fall on the deck, or warming-up platform, thus creating a serious fire hazard.

After three unsuccessful attempts to start the engine by priming, remove the spark plugs and spray a small amount of warm oil into each cylinder to insure proper lubrication and compression and prevent damage to the cylinder walls. Should an engine be permitted to stand idle for a day or more after attempting unsuccessfully to start it, protect the piston rings and cylinder walls from rusting by a fresh application of oil.

A discharge of fuel from the supercharger does not necessarily indicate overpriming in cold engines during cold weather. Since only the lighter fractions of the gasoline vaporize at low temperatures, the heavier fractions will remain as a liquid. A certain amount of the fuel that doesn't vaporize collects in and drains from the supercharger. At

low temperatures, it is possible for the engine to be insufficiently primed even though fuel is flowing from the supercharger. The presence of raw fuel in the exhaust collector, however, is an indication of sufficient priming, and may be an indication of overpriming.

Overpriming may prevent the engine from firing, or may result in only a few explosions, with white smoke coming from the exhaust.

In case the engine has been overprimed, it will be necessary to clear the cylinders and induction system of the excess fuel. This may be done by turning the engine over several revolutions in the normal direction of running, not backwards, with the throttle wide open. When the exhaust valves open, the excess fuel is forced out. If the carburetor has an idle cut-off, place the mixture control in the idle cut-off position. Turning the engine backward will not help to rid the cylinders of excess fuel. It will clear the cylinders but will deposit the excess fuel in the induction, whence it will be drawn back into the cylinders when the engine is turned forward again.

STOPPING WITH IDLE CUTOFF DEVICE

When the engine has idled long enough to cool off properly, place the mixture-control in the idle cutoff position with the throttle closed. When the engine stops firing and the propeller comes to a complete stop, turn the ignition switch to the off position. If the engine has idled for a long period, considerable fuel may have collected in the induction system and the engine will not stop promptly when the idle cutoff device is operated. This trouble can easily be overcome by opening the throttle to a position which would ordinarily give 500 r. p. m. and the engine will stop at once.

All airplanes equipped with carburetors having an idle cutoff feature have the last 10 degrees on the lean side of the mixture-control segment in the cockpit marked RED, to show the correct position of the mixture-control lever for stopping the engine.

Adjustments made by operating personnel on float-type carburetors are those of the idling speed and mixture. The following instructions will cover these points, and you should follow them carefully and in the order given when adjusting the carburetor.

First, set all idle-mixture adjustments in the mid position of their travel before starting the engine. Next, run the engine long enough and at a speed high enough to insure that all spark plugs are firing, and set the throttle stopscrew at a point that will give a speed of 450 to 500 r. p. m. Note the manifold pressure. If the engine has been run at high speed and is quite hot, allow it to idle at approximately 1,000 r. p. m. for 5 minutes before attempting to set the idle adjustment.

When the engine speed has been stabilized move all the idle adjustments one notch leaner. Repeat the procedure until the setting has been determined at which the manifold pressure is the lowest and the engine speed the highest for the fixed-throttle position. The increase in engine speed is usually noticeable by the sound. If, after you have moved the adjustments one or two notches, the speed decreases and the manifold pressure increases, return the adjustments toward the rich side, one notch at a time, until the revolutions per minute of the engine become a maximum and the manifold pressure a minimum. Wait at least 15 seconds after each change to be certain the conditions are stabilized.

With the idle-mixture adjustment levers remaining fixed, reset the throttle-stop adjusting screw for an engine speed of 450 to 500 r. p. m., and repeat the procedure described in the preceding paragraph until you are certain that the mixture is the best obtainable at the reduced throttle opening—that is, the greatest engine speed and the lowest manifold pressure at the fixed-throttle position. You will sometimes find it necessary to repeat this last step two or three times to insure proper engine operation.

In case the engine operation is apparently the same in any of several notches, place the adjustment levers in the notch giving the leanest position, but under no circumstances lean

the idle-mixture levers beyond the point of maximum speed. Such action would result in hard starting, continual backfiring during the warmup period, and poor acceleration.

To prevent the idle-discharge nozzles from being "frozen" to the body of the carburetor by corrosion, move the idle-adjustment lever that rotates the idle-discharge nozzle in the throttle-valve, at every 30-hour check.

When any part of the mixture-control and the primer shaft of the NA–R9B carburetor are being replaced, take particular care that they are assembled correctly. Lap the primer valve to its seat with a very fine grinding compound. When the lapping is finished, check the valve carefully to see that it shuts off the fuel from the accelerating-pump discharge nozzle when the mixture-control is in the full-lean position and the throttle is operated. Be sure to assemble the lever stop in the correct position relative to the offset, or eccentric, pin that operates the the mixture-control needle.

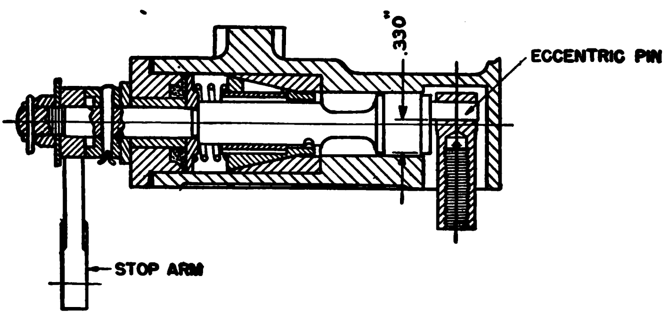


Figure 59.—Correct setting of mixture-control stop and stem.

To do this, first make up the complete assembly, including the lever, and the indicator plate and nut, and assemble it in the body. Hold the lever stop against the screw with the large head, the full-rich position, and turn the shaft until the bottom of the pin is exactly .330 inch from the lower edge of the shaft. This dimension is indicated in figure 59, being measured between the points of the two arrows. When this adjustment has been made, drill a small hole through the stop and into the shaft, and drive a pin into it, so as to hold the stop permanently in place.

The mixture-control needle is screwed into the needle holder, and the needle should be adjusted in the holder so that it will have a travel of $^{17}/_{64}$ inch, and give a lever travel of from 75 to 80 degrees. Under no circumstances should the needle-valve travel be more than $^{17}/_{64}$ inch, but no harm is done if it is $^{1}/_{64}$ inch less. Make an approximate adjustment before assembling the needle valve in the upper part of the carburetor, by setting the bottom of the holder slot $^{15}/_{32}$ inch from the main body parting surface with the needle valve held against its slot. You will see this position in figure 60, view (*A*).

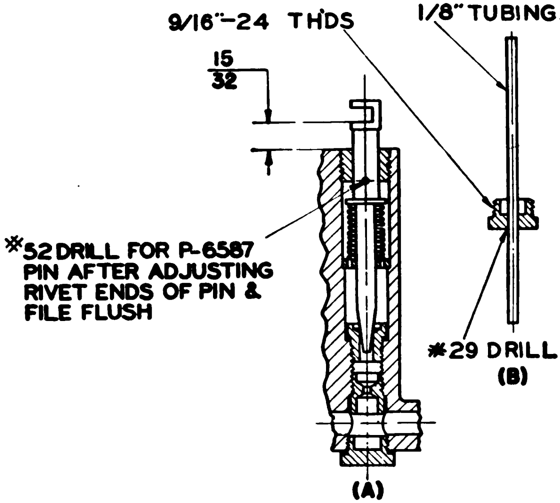


Figure 60.—Preliminary adjustment of mixture-control needle valve and holder on NA-R9B carburetor.

Having made this preliminary adjustment, assemble the two halves of the carburetor, and check to see if the needle has $^{17}/_{64}$ inch—or slightly less—travel, as stated. Check the travel by removing the jet and plug below the needle, and screwing into the plug threads the device shown in view (*B*). Measure the travel of the tubing when the needle valve is moved from its full-rich position—stop arm against stop lug—to the full-lean position in which the needle valve is on its seat. When the adjustment is correct, pin the needle in

place in the holder, as shown. When assembling the needle in the carburetor, place the open end of the slot in the holder away from the pump mechanism.

OVERHAULING FLOAT-TYPE CARBURETORS

Disassembly.—Each time that the engine is given a complete overhauling, disassemble the carburetor for cleaning and inspection. You will find the order of procedure given here a good one to follow.

Remove the carburetor, the hot spot, and air intake, or heater, from the engine. Separate the halves of the carbu-

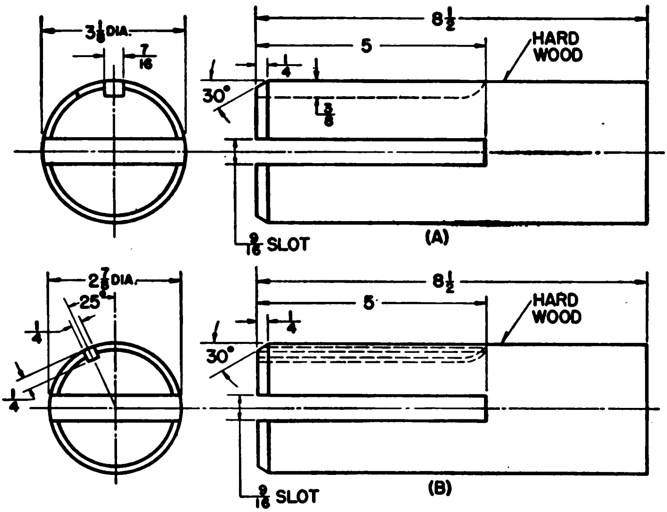


Figure 61.—Wooden plugs for removing venturi from carburetors NA–R9B and NA–R9C2.

retor by removing the screws that hold them in place, and also remove the venturi set-screw. The economized needle, the mixture-control needle, pump sleeve, and the venturi will be held in the throttle body.

Slip the accelerator-pump sleeve off the operating stem as soon as the parts are separated, as it is a brass stamping and is easily bent if allowed to drop to the floor or bench.

If necessary to remove the venturi tube, drive it out with

a wooden plug made somewhat as shown in figure 61, the plug for a NA–R9B carburetor being shown in view (*A*), and that for the NA–R9C2 in view (*B*).

Remove all parts of both assemblies, with the possible exception of the idle discharge-jet assemblies.

CLEANING AND INSPECTION

Clean the carburetor bodies and all parts thoroughly with gasoline, and blow out all passages with compressed air. Check all parts that have variable sizes to see that the sizes used are in accordance with the latest specification sheet for the engine on which you are working. Inspect all moving parts to see that they move freely but do not have excessive clearance.

REASSEMBLING

When reassembling the carburetor, there are two important points that you must observe when putting in the headless screws. Below the fuel level, assemble all headless screw plugs with shellac, but be careful that none of the shellac gets on the end of the plug where it will come in contact with the fuel, and be carried into one of the metering orifices. Above the fuel level, place a compound of graphite and castor oil on the threads of headless-screw plugs and other parts that screw into the body.

Fit the throttle valve so that when it is in its closed position practically all light will be shut off. If a new float needle valve or needle-valve seat is needed, replace both assemblies at the same time. It is very difficult to fit a new needle to an old seat, or a new seat to an old needle.

Place a new gasket under the needle-valve seat and then check the float level. This should be done under the same conditions that would exist in service as regards the fuel used and the pressure, or head, at the carburetor. The float level should be three-fifths of an inch, and you can make an adjustment, as necessary, by varying the thickness of the gasket under the needle-valve seat. On carburetors that have a $\frac{5}{16}$-inch needle-valve—which is the type used with a gravity-feed system in which the head is less than 97

inches—use a 1-pound pressure when setting the fuel level. Carburetors used with gravity systems having a fuel head of more than 97 inches, or with a fuel-pump system, are equipped with a 196-inch needle-valve seat, and have the fuel level set at a 3-pound pressure. Be sure to note this difference in setting the float level.

If the level is found to be incorrect after reassembling, remove the needle valve and install thicker gaskets under it to lower the level and thinner gaskets to raise the level. The reason for this is that the higher the seat, the sooner the needle valve will come in contact with it and shut off the fuel. A change in gasket thickness of $\frac{1}{64}$ inch will change the fuel level approximately $\frac{5}{64}$ inch.

ECONOMIZER

The position of the economizer-needle adjusting nut in the NA–R9B carburetor determines the engine speed at which the needle is lifted off the seat. Be absolutely sure that this is set correctly in order that the fuel mixture will not be too rich at cruising speeds, or too lean near full-throttle openings. You will find the throttle opening at which the economizer should come into action given in the specification sheet as the economizer setting. This is the travel in degrees of the throttle-valve lever from its closed position to the point where the forked lever on the throttle shaft engages the nut on the top of the economizer needle.

To find the angle that the throttle valve makes with the horizontal flange surface of the carburetor when the economizer comes into action, add the angle at which the throttle valve stands when in the normal closed position to the angle through which the economizer lever moves to come into contact with the economizer adjusting nut. Thus, if the angle of the throttle valve is 20°, for instance, and the economizer setting is 30°, the angle that the throttle valve makes with the horizontal flange is $20° + 30° = 50°$. This all sounds rather complicated, but a look at figure 62 will enable you to understand it without difficulty.

In case it is necessary to replace the mixture-control valve

plates in a NA–R9C2 carburetor, lap them in with a very fine lapping compound, so that there will be no possibility of an air leak.

When the assembly of this carburetor is completed, set the economizer to open at the point specified on the specification sheet. To set the economizer, proceed as follows, using figure 68 as a guide.

Plug up the suction tube that extends through the wall of the venturi, then remove the ⅛-inch pipe plug from the side of the economizer cover, and, at this opening, make a connection with some source of vacuum. Remove the 10/32 plug from the economizer adjusting screw in the center of the cover, and insert through the opening the leg of an Ames dial gage, so that it will rest against the economizer-needle stem. Connect a water manometer at the 10/32 connection shown at the righthand side of the illustration, so that the

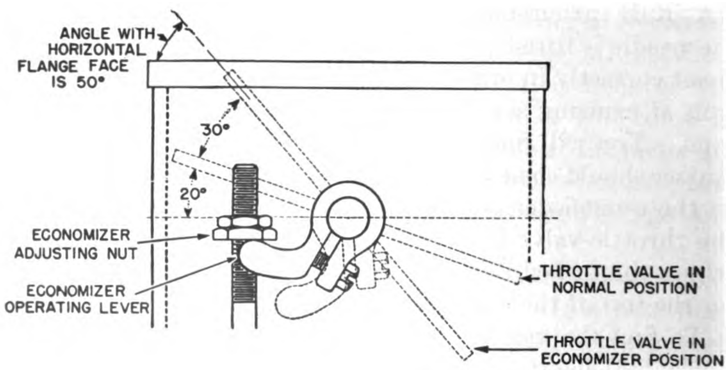


Figure 62.—Method of measuring angle at which economizer comes in on NA–R9C2 carburetor.

correct suction applied to the vacuum chamber will be read in "inches of water." Now apply suction to the chamber and watch the Ames gage and the water manometer carefully.

At the exact instant the Ames gage pointer starts to move, indicating that the economizer needle has started to move, note the manometer reading. If the economizer opening point differs from that specified on the specification sheet,

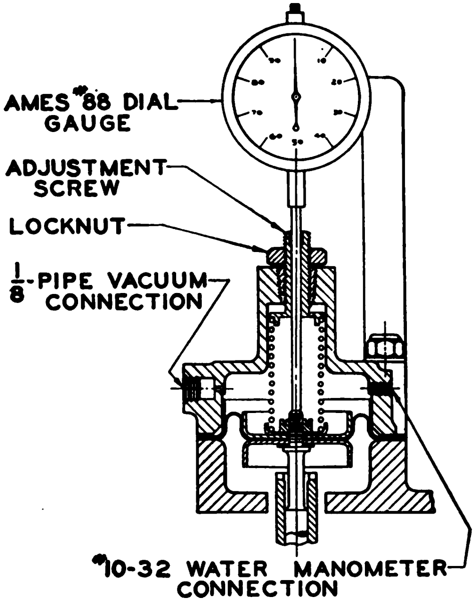


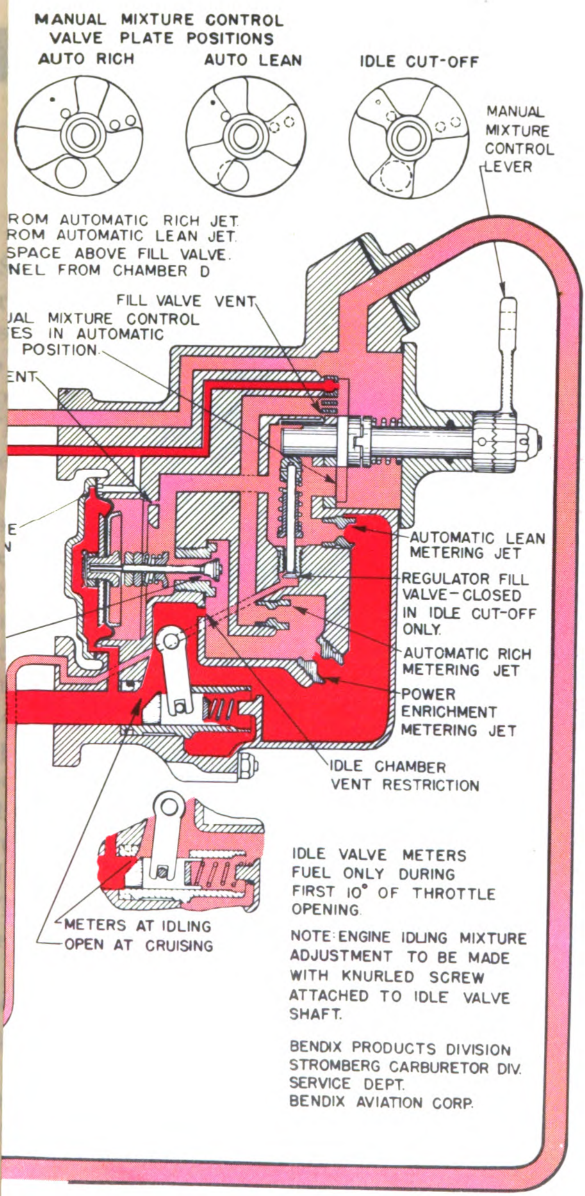
Figure 63.—Method of setting economizer on NA–R9C2 carburetor.

loosen the locknut on the adjustment screw, and turn the screw until the correct opening point is indicated.

Since it is essential that there be no leaks around the carburetor gasket or at other assembly points, you should make an underwater test of the carburetor before installing it on the engine. To do this, assemble plates and gaskets to both carburetor flanges, and apply an air pressure of 3 to 5 p. s. i. to the inside of the carburetor through a connection made in one of the plates. Immerse the carburetor and watch for air bubbles. Never apply more than 6 p. s. i. pressure, as this would be liable to damage the float. Mark any points of leakage and make the necessary repairs. Finally, safety-wire the carburetor before installing it on the engine.

QUIZ

1. How does throttle-lever control-rod movement compare on Stromberg NA–R9B and NA–R9C$_2$ carburetors?
2. (a) Which of the two Stromberg carburetors described in this chapter uses a venturi-suction-operated economizer? What kind of economizer does the other use?
   (b) Which of these carburetors has a built-in primer? Which has a cruise valve?
   (c) What type of mixture-control system does each use?
3. (a) Why is fuel dripping from the supercharger a bad sign in warm weather?
   (b) Is it always a bad sign in a cold engine in cold weather? Explain your answer.
4. (a) What should the float level be, in a float-feed carburetor?
   (b) If the float level is incorrect by $\frac{5}{32}$ inch, how much will you have to change the gasket thickness?
5. What is the general testing procedure for leaks around the carburetor gasket or at other assembly points?
6. What device operates the needle valve in the automatic mixture-control unit of the NA–R9C$_2$ carburetor?
7. Why are the last 10 degrees on the lean side of some mixture-control segments (in the cockpit) marked red?
8. What thread compound should you use on headless screw plugs?
   (a) Above the fuel level?
   (b) Below the fuel level?
9. When cleaning the main jet of the NA–R9B carburetor, the ____________________ is removed.
10. In case the engine has been overprimed, clear the cylinders and induction system of ____________.
11. Operating personnel adjustments to float-type carburetors are those of the ____________ and ____________.
12. To prevent the idle-discharge nozzles from being "frozen" to the body of the carburetor, move the idle-adjustment lever at every ____________.
    a. 30-hour check.
    b. 60-hour check.
    c. 90-hour check.
    d. 120-hour check.
13. Disassemble the float-type carburetor for cleaning and inspection each time that ____________.
14. Passages in carburetors are cleared by ____________.
15. When making an underwater test of a carburetor never exceed a pressure of ____________ pounds per square inch.



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CHAPTER 8

STROMBERG INJECTION CARBURETOR

WHAT IS IT?

So far, you have become acquainted with only one type of carburetor—the float-feed type—familiar because of its long association with automobiles. From here on, you will meet up with carburetors that operate on entirely different principles.

The Stromberg injection carburetor, which is the first of the non-float feed type to be discussed here, differs from the conventional carburetor, in that it employs a closed-feed system from the fuel pump to the discharge nozzle. The fuel spray is atomized under positive pump pressure, and metered through orifices according to the venturi suction. The injection carburetor is an assembly of five separate units, each of which has its own individual duty and function. These are the throttle body, a mixture-control unit, a regulator unit, a fuel-control unit, and usually an adapter—depending upon the engine installation. To assist you in understanding the function of these different parts and their relation to each other, they are shown in the schematic view, figure 64. Please follow this diagram closely in reading the following description.

The throttle body, which is somewhat similar to that of the float-feed carburetor, consists of one or more barrels, each of which contains a large venturi, a small or boost venturi, and a butterfly-type throttle valve. The number of barrels is governed mainly by the size and air capacity of the engine. In supercharged engines of high horsepower, two or three barrels may be required to provide proper distribution and prevent the starving of cylinders at high engine speeds. The letter in the model designation of the carburetor indicates

the number of barrels, as D for double-barrel, and T for triple-barrel, and the number indicates the outside diameter of the carburetor barrel. The venturi may be machined to any of a number of diameters for a given barrel size, in order to meet the airflow requirements of different engines.

When the engine is running, the suction created at the throat of the small venturi is a measure of the amount of air taken into the engine, and when corrected for changes in air density by an automatic moisture-control unit, as will be explained, it becomes a measure of the mass (weight) airflow, and is applied to an air diaphragm to regulate the fuel-metering pressure.

The fuel-discharge nozzle is located in the adapter, if one is used, and as far beyond the throttle as possible. Since only air passes through the carburetor, this arrangement serves to prevent the formation of ice in the carburetor as a result of the vaporization of fuel. However, the temperature of the air in the air scoop must be above freezing to prevent icing, if there is moisture present.

The air flow through the carburetor is controlled by the butterfly throttle valves which are synchronized—they open and close in exact unison—and are operated by the throttle-valve lever. A rotary valve to bypass the automatic mixture-control and make it inoperative is included in the throttle body, and is connected through suitable linkage to the mixture-control lever. The automatic mixture-control unit is mounted on the throttle body, and maintains a correct fuel-air ratio in the carburetor, under conditions of varying atmospheric pressure and temperature.

Another of the carburetor units mentioned is the PRESSURE-REGULATOR UNIT, which is fastened to a flange on the throttle body and automatically adjusts the fuel flow and pressure across the metering jets in proportion to the air flow through the throttle body. Fuel enters the regulator through a strainer unit and the flow is regulated by an air diaphragm, a fuel diaphragm, and a balanced valve, all mounted on one stem. A vapor separator is provided in the strainer chamber to prevent vapors from entering the regulator and forming a

vaporlock. The separator consists of a small vent valve held closed by a float, which is normally submerged in the fuel in the strainer chamber, and which drops to allow vapors to escape through the vent connection at the top of the chamber, as the pressure of the vapor causes the level of the liquid to lower.

The FUEL-CONTROL UNIT is attached to the regulator, and contains the metering jets, fuel-head power-enrichment valve, idle valve, and manually operated mixture unit. The mixture-control unit consists of a manually operated lobed valve which rotates over a drilled stationary valve, the parts being shown separately at the upper right-hand corner of the diagram. The holes in the stationary valve are connected by channels to the various metering jets, and their operation is controlled by the movable plate. The idle valve is connected to the throttle lever by suitable linkage and controls the mixture for idling speed. A knurled screw is provided on the outside of the carburetor to adjust the idle mixture. A throttle stop is provided to give the approximate speed desired and the idle mixture is then adjusted for smooth operation.

A line supplies fuel from the control unit to an adapter in correct proportion to the engine speed and the airflow through the barrels of the throttle unit. The adapter unit is placed between the carburetor and the supercharger, and consists of a vacuum-operated or throttle-operated, accelerator pump, and nozzles for spraying the fuel evenly across the face of the supercharger.

HOW IT WORKS

Now, you have a general idea of the layout of the Stromberg injection-type carburetor, and can go a little further and see how it works. Don't worry about the actual construction details—we'll get to them in good time—but first be sure that you understand how the carburetor functions.

Referring again to figure 64, air enters the carburetor through the air scoop, which may be provided with a valve so that the air can be taken from inside or outside the cowl-

ing. Hot air to the carburetor is not required under normal conditions, but at times, such as when ice is forming on the airplane, there may also be a tendency for ice to form on the screen of the air scoop, and this tendency may be eliminated by an air duct inside the cowling.

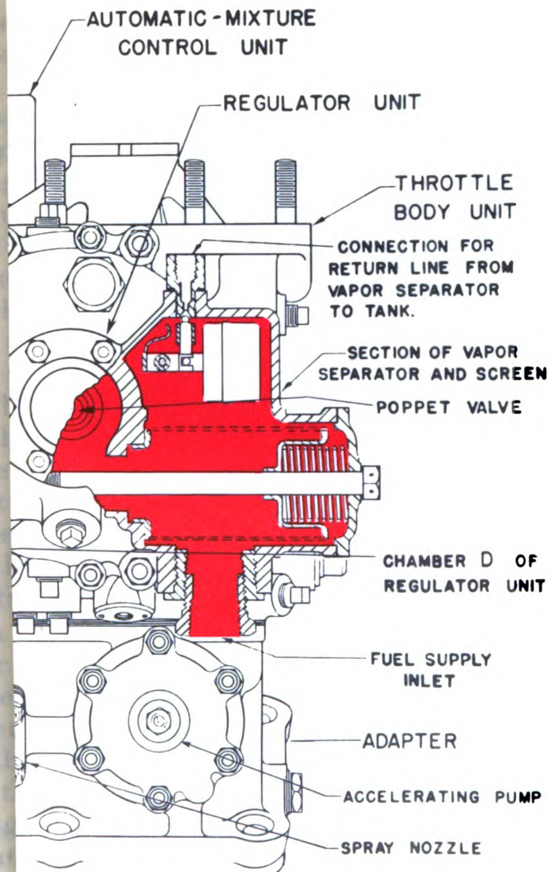
As air enters the carburetor barrel from the air scoop, part of it goes through the boost venturi, and part goes around the boost venturi and through the main venturi. A number of tubes, known as IMPACT TUBES, are open at one end to the main venturi, and at the other end to a space around the main venturi, which is in communication with the automatic mixture control. Part of the air entering the carburetor goes through these impact tubes, and as the pressure of the air through the tubes is the same as that entering the carburetor, the tubes register scoop pressure.

The outlet of the boost venturi is at the throat of the main venturi, so that, as the name implies, the suction produced at the throat of the boost venturi is several times greater than that at the throat of the main venturi. This results in a marked increase in the metering range, and in the accuracy of the mixture regulation. The resistance or the loss of airflow capacity of the main venturi, because of the use of the boost venturi, has been proven by tests to be very small.

A particular feature of the Stromberg injector carburetor is that no fuel is discharged into the venturi, and this gives a greater airflow since the flow capacity of a venturi is greater when only air flows through it. The throttle is located at the bottom of the throttle body and above the fuel-discharge nozzle, so that it will not be chilled by the temperature drop resulting from the vaporization of the fuel. The effect of pressure drop between the top and bottom flanges of the injection carburetor is very little in contrast to other types of carburetors. This means that for the same weight of air passing through the carburetor, there will remain a constant mixture even though the revolutions per minute of the engine, are varied or the throttle opening is changed.

The pressure-regulator unit controls the flow of fuel from

ETERED FUEL FROM REGULATOR CHAMBER C



the supply line. It consists of an air section and a fuel section, both assembled as a single unit. The air section is divided into chambers for easy identification by means of a diaphragm (fig. 65). The fuel section, which is of the same capacity and acts on the same pressure difference as the air section, is divided into two chambers—marked *C* and *D*—by a second diaphragm. A poppet valve mounted on a stem that is supported in suitable guides, is attached to the diaphragm so that any movement of the diaphragms will cause a corresponding movement of the valve. When the engine is in operation, the difference in pressure acting on the diaphragm in the air section and that in the fuel section of the regulator, automatically regulates the fuel flow by opening and closing the poppet valve.

If you will take a good look at figure 68 you will see that the small—or boost—venturi is connected by an air passage leading from the venturi throat to air chamber *B* of the air section, and chamber *B* is therefore subject to venturi suction. Chamber *A* on the other side of the diaphragm is connected through a channel that leads from a space around the large venturi which is open to the air scoop through the impact tubes. Chamber *A* is therefore under scoop pressure. The pressure difference between the two chambers is a measure of the air flow through the carburetor. The action of the control unit is as follows.

When the throttle valve is open, a pressure is created in chamber *A* by the flow of air through the impact tubes. At the same time, the reduced air pressure at the throat of the boost venturi causes air to be drawn from chamber *B* and lowers the pressure in that chamber. The unbalanced pressure on the diaphragm between the two chambers causes the diaphragm—and hence the poppet-valve shaft—to move to the right and open the valve in the fuel section of the regulator. This is the air-metering force, and, when it is decreased by closing the throttle, the diaphragm moves back to the left and closes the valve.

An engine-driven fuel pump delivers fuel to the carburetor at the inlet shown, whence it passes through the strainer

screen and the poppet valve as unmetered fuel into chamber D. All fuel chambers and passages are indicated in red on the diagram, that part of the fuel under pump pressure being further indicated by crossed lines—known as cross-hatching. You will see the float and needle valve of the vent in the strainer chamber just above the screen. As has been stated before, precautions must be taken in airplane systems to overcome the tendency toward vapor-locks, and this is done in the strainer chamber by means of the vent. When there is a sufficient accumulation of fuel vapor in the chamber to allow the float to lower, the needle valve drops with the float lever, and permits the vapor to escape through the vent line until the strainer chamber is again filled with fuel. The fuel flows out of chamber D to the fuel control shown at the right end of the diagram. This strainer assembly is shown also in figure 65, in its proper relation to the regulator unit.

IDLING RANGE

The fuel enters the control unit past an idle valve, which meters the fuel during the first 10° of throttle opening. The idle valve in the metering position is shown in the small separate section directly below the control unit. At throttle openings above 10°, the idle valve is moved out to its full-open position and the mixture is controlled by the metering jets, the power-enrichment valve, and the manually-operated mixture selector, as will be explained later. The maximum richness that can be obtained within the idling range—from 0 to 1,900 pounds of air per hour—is determined by the setting of the idle spring. This is the flat-blade spring above and to the left of the poppet valve. The adjustment screw is located on the back of the regulator. At idling conditions, the metering force caused by the movement of the diaphragm in chamber A of the mixture-regulator unit is not great enough to open the poppet valve, but the idle spring holds the valve open sufficiently to give the necessary fuel flow and metering pressure at idling.

The idle-spring setting is too rich for normal operation. The necessary adjustment for idling is made by varying the

position of the contoured idle valve in the fuel-control unit. The idle valve is connected by suitable linkage to the throttle valve, so that the idle valve is completely opened at about 10 degrees of throttle opening. An adjusting screw for the idle valve is provided on the operating lever.

The unmetered fuel flowing out of chamber *D* enters the fuel-control unit through the lower connecting flange, and is metered through the idle valve with a metering head equal to the pressure difference between chambers *C* and *D* in the mixture-regulator unit. You can grasp this if you stop to think that when a flexible partition such as a diaphragm separates two compartments, both filled with a liquid—which is practically incompressible—a movement of the diaphragm in one direction or the other means that something has to "give," and when an outlet is provided the liquid will naturally escape through it.

The fuel having passed the idling valve is now considered as metered fuel—shown in pink in detail in the lower right-hand corner of figure 64 and passes through the automatic-lean metering jet and out through the control plate and the fuel line to the spray nozzles. Different adjustments of the idle-valve adjusting screw give the necessary variations of idle-mixture ratios in the low-throttle range.

CRUISING RANGE

When the throttle valve has moved beyond 10 degrees, the idling valve is wide open and the metering shifts from the opening between this valve and its seat to the AUTOMATIC-LEAN METERING JET, and the AUTOMATIC-RICH METERING JET. When the mixture-control lever is in the AUTO-LEAN position, the lobes of the movable control-mechanism plate cover the opening from the automatic-rich metering jet, as shown in the auto-lean position of the valve at the top of figure 64. The only opening through which the fuel can pass to the discharge nozzle is then from the automatic-lean jet, and the fuel flow is reduced. The passage of the fuel through the control unit in the auto-lean position is shown in the schematic diagram, figure 66.

To obtain the additional richness of the mixture requi for the power range, the carburetor is provided with a f head power-enrichment valve as a part of the fuel-cont unit. By looking at figure 64, you will observe that t device consists of a stem, one end of which carries a tape head, with the other end anchored in a diaphragm. The

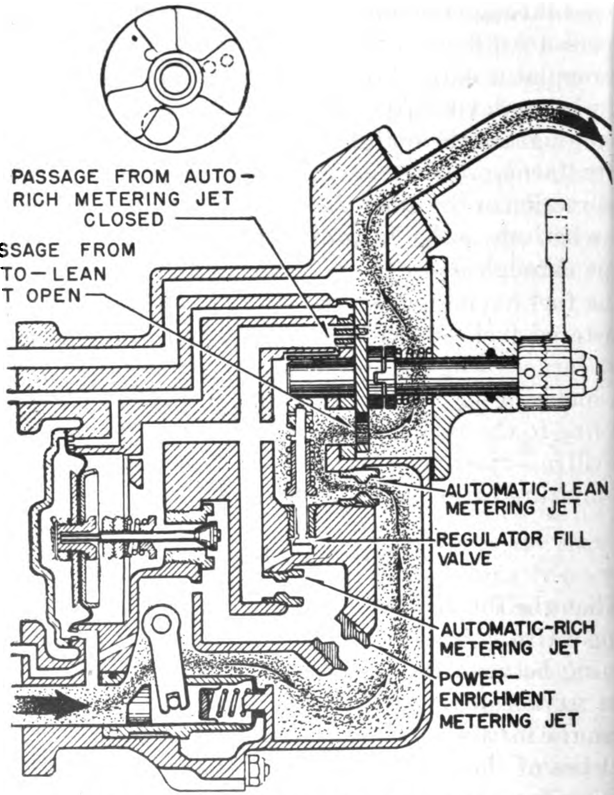


Figure 66.—Stromberg injection carburetor in automatic-lean position.

phragm is operated by the pressure of the unmetered fuel which enters a chamber behind the diaphragm through channel leading to the fuel inlet of the fuel-control unit. The extent of this pressure depends upon the difference in pressure of the unmetered fuel in chamber *D* of the mixture-

control unit and that of the metered fuel in chamber *C*. These pressures depend upon the mass, or weight, of airflow to the engine.

With the manual control valve in the FULL-RICH position (see view of valve at top of fig. 64) and the throttle opened,

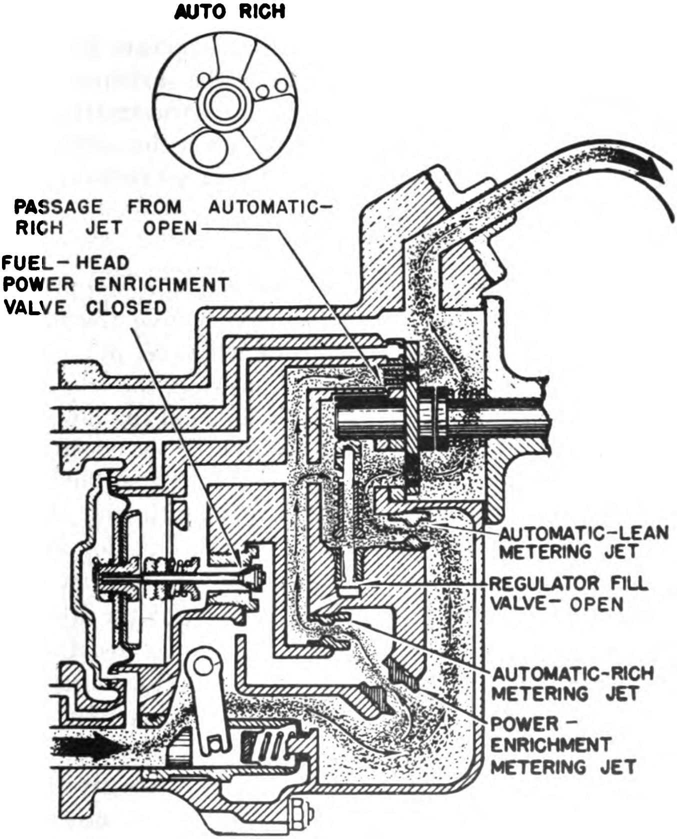


Figure 67.—Stromberg injection carburetor in automatic-rich position—power enrichment valve closed.

the mass airflow to the engine increases and the fuel-head power-enrichment valve starts to open. Then part of the fuel entering the fuel-control unit flows through the automatic-lean metering jet, another part through the automatic-rich metering jet, and still another part through the enrichment

valve. The paths of the fuel just before the enrichment valve opens are shown in the schematic view, figure 67. As the engine speed increases, and with it the mass airflow through the carburetor, the enrichment valve is moved further away from its seat, and, because of its tapered seat, allows more fuel to go through the valve.

The rate of enrichment with increased power is also dependent upon the rate of the spring on the enrichment-valve stem. This spring is somewhat similar to the familiar automobile valve spring, and operates in much the same way to close the enrichment valve when the pressure on the diaphragm lessens.

IDLE CUT-OFF

The idle cut-off position is provided for stopping the engine. This position is obtained by moving the manual-control lever to the extreme limit of its travel in a counterclockwise direction. When in this position, the lobes of the movable valve completely cover the holes in the lower fixed plate—as you will see in the last diagram of the control valve at the top of figure 64—thus cutting off all fuel flow except that through the very small orifice venting the top of chamber *D* to chamber *C* in the regulator unit. This flow is insufficient to run the engine. It is only when the manual-control lever is in IDLE CUT-OFF position that the regulator fill valve is closed. The closing of this valve prevents metered fuel from flowing through the FILL VALVE to channel *C* of the regulator.

Here is a brief summary of the operation of the fuel-control unit. The idle valve is operated by the throttle. A pilot's manual-control lever is connected to give in one extreme position an "IDLE CUT-OFF," then, in succession, a position for automatic-lean cruise—AUTO LEAN—in a position for automatic rich cruise—AUTO RICH—and finally the opening of the fuel-head power-enrichment valve, which will give a FULL-RICH setting.

In all positions, except for the idle and fuel-enrichment valve, all manual mixture settings are automatically held uniform through changes of altitude and temperature, and

the desired fuel-air ratio is not disturbed by change of throttle position, engine speed, or propeller pitch.

Now let's take a little closer look at the pressure-regulator unit, which is shown in detail, figure 68. In addition to the fuel and air diaphragms previously mentioned, you will notice a pair of smaller opposed sealing diaphragms—one in chamber *A* and the other between chambers *C* and *D*. A small balanced diaphragm is also used on the poppet valve. The diaphragm, spacer, and the poppet valve are assembled on one stem and moved as a single element.

The regulator unit is fastened to the throttle body and the fuel-control body. You will see outlined in dotted lines, the passage in the throttle body that connects chamber *A* with the impact tubes through the automatic mixture-control channel, and the channel that connects the boost venturi with chamber *B*. A fuel passageway—pink—shown in figure 65, leads from chamber *C* through the top flange to the metered side of the fuel-control unit. The purpose of this passage is to permit air or vapor in chamber *C* to pass into the control unit, and thence out of the carburetor. Fuel under pressure from the supply pump enters the mixture-regulator unit through the strainer and vapor separator, passes through the poppet valve into chamber *D*, through a passage in the bottom flange of the regulator unit, and to the metering jets in the fuel-control unit. A return passageway through the bottom flange permits metered fuel to fill chamber *C* at metered pressure.

In figure 68 at the right-hand side of the mixture regulator is a small passageway with a control air bleed, which connects the top of chamber *C* to the top of chamber *D*. Air collecting in chamber *D* passes through the bleed to *C*, and is carried out of the regulator with the metered fuel.

AUTOMATIC MIXTURE-CONTROL UNIT

The automatic mixture-control unit is used on all Stromberg injection carburetors, and is of the same type as already described in connection with float-type carburetors. The unit is furnished in several types, having variations in the

covers, screens, size of the threads on the mounting bases, and the taper of the needles. The same bellows is used in all types.

The bellows and spring are carefully calibrated to insure the proper responsive rates. The valve points are specified by letter and number to designate their taper. The complete calibrated unit is a self-contained assembly which is screwed into the throttle body. In making an installation of an automatic mixture-control unit, be sure that you use the same type as the one removed.

The automatic mixture-control seal and needle are assembled in the passage behind the venturi, to which passage the impact tubes are connected, and the needle controls the part of the impact pressure that is imposed upon the diaphragm in chamber *A*. By providing the proper taper on the mixture-control needle, the air metering force can be regulated to maintain a constant mixture at varying air-scoop densities. In the manual setting of the mixture control, the round valve is rotated so that its slot is vertical, and the position of the automatic unit has very little or no effect on the mixture.

ADAPTERS AND ACCELERATOR PUMPS

The spray nozzles are usually mounted so as to spray fuel into the supercharger. If the design of the engine itself does not allow for the mounting of the nozzles, they can be mounted in an adapter casting, which is placed between the supercharger and the carburetor. When an adapter is used, an accelerator pump may be mounted on the adapter, or at some other point. In figure 69 you will see a double-diaphragm accelerator pump, which is operated by vacuum. This type of pump performs the double function of causing an accelerating discharge through a spring-controlled check valve and passage directly into the air stream before it enters the supercharger, and also causing an extra—or accelerating—discharge through the regular spray nozzles. Two diaphragms are required to produce the compound action, which takes place in the following manner.

The metered fuel from the control unit of the carburetor

passes through a pipe on the outside of the carburetor and enters the adapter, whence it enters a channel leading both to the discharge nozzle and to fuel chamber *A* of the accelerator pump. The pump discharge valve is held to its seat by a coiled spring backed by a diaphragm, except during an accelerating charge. A small channel (fig. 69) leads from fuel chamber *A* to a small metering opening. A control bleed is thus effected from chamber *A* to chamber *B* on the other side of the diaphragm. You will note still another passage leading from the vacuum chamber *C* to the carburetor barrel just below the throttle.

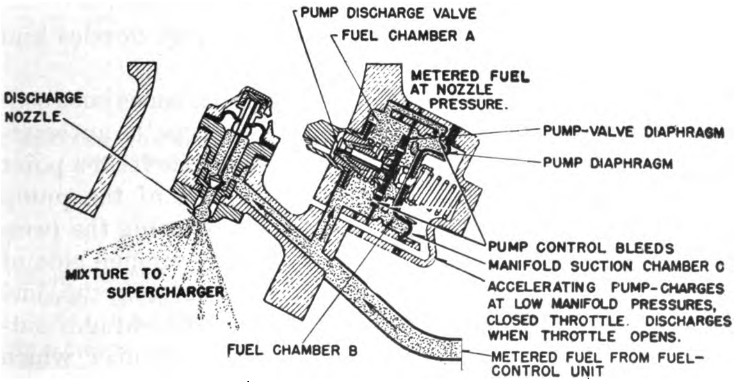


Figure 69.—Injector carburetor adapter with double-diaphragm accelerator pump.

When the throttles are closed, the pressure below them and in vacuum chamber *C* is reduced. The difference in the pressure between fuel chamber *B* and vacuum chamber *C* produces a force that moves the diaphragm between the chambers outward—to the right in the illustration—on a suction stroke, and compresses the outer pump spring. The outward movement of the diaphragm causes fuel to be drawn into chamber *B* through the control bleed from the nozzle passage.

When the throttle is opened, the pressure is suddenly increased on the diaphragm from chamber *C*, and the spring in this chamber, in turn, pushes the diaphragm in suddenly toward the adapter and increases the pressure on the fuel in

chamber B. The pressure on the fuel in chamber B is transmitted to the diaphragm between chambers A and B and overcomes the spring pressure tending to hold the pump valve closed. The valve then opens. The pressure on the fuel in chamber A is at the same time increased suddenly, and the fuel discharges through the check valve directly into the air stream to the supercharger. The increased pressure in the fuel in chamber A also acts on the fuel in the passage leading to the regular spray nozzles, thereby causing an accelerating discharge to take place at these nozzles also. As the outer diaphragm moves inward, the fuel in chamber B is forced out at a controlled rate through the control bleed, and into the passage leading to the discharge nozzles and chamber A.

The diaphragm type of accelerator pump is sometimes constructed with a single diaphragm. This type is automatically operated by vacuum. A passageway leads from a point below the throttle valve to the vacuum side of the pump diaphragm. When the throttle is closed, reducing the pressure below it, the pressure is reduced on the vacuum side of the diaphragm. The pressure difference between the fuel side and the vacuum side moves the single diaphragm outwards, and produces a suction in the fuel chamber which draws fuel into the chamber, and, at the same time, compresses the diaphragm spring. When the throttle is opened, the pressure is increased on the vacuum side of the diaphragm, and the spring pushes the diaphragm inward, forcing fuel through the pump passages and into the nozzle passage, causing fuel to be discharged quickly through the regular spray nozzles. A separate accelerator valve is not used with this method.

The late-model, large-capacity injection carburetors are equipped with a manual type of accelerator pump. This pump, which is throttle-operated, originated when the R–2800B P. & W. engine was developed. This design was necessitated by the fact that the R–2800 engine has high overlap valves, and thus the vacuum beneath the throttle at low speed is too low to operate a vacuum pump. The first type

of throttle-operated pump developed works on the same principle as the vacuum pump with the exception that the fuel pressure built up is developed by a piston, and the diaphragm is replaced by another piston connected to the pump valve. Both pistons slide within the same sleeve.

This first type of manual accelerator pump was discarded because of trouble experienced with the plunger valve. The second type, which is the one now in use, has the same external appearance as the twin-piston type. However, the pressure built up by the actuated piston is transferred to the balance chamber of the pressure-regulator poppet valve of the carburetor. This increased pressure upsets the balance

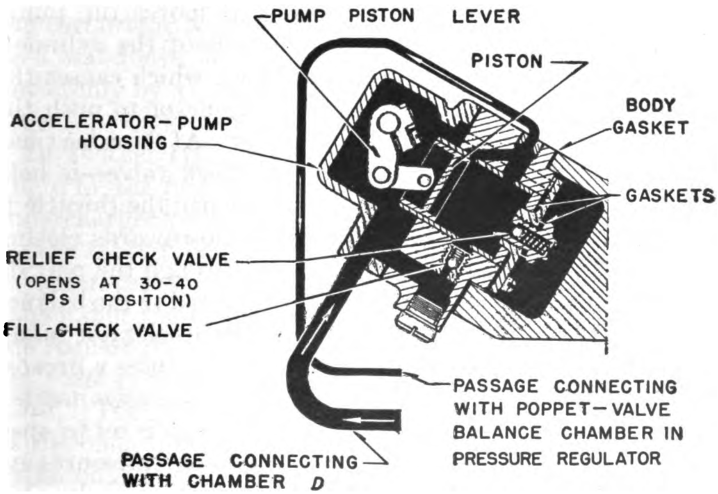


Figure 70.—Throttle-operated accelerator pump.

in the fuel system, and causes the poppet valve to open momentarily and allow an increase in fuel flow to the engine discharge-nozzle. The system regains balance when the increased pressure is eased off through two bleeds that connect with the unmetered fuel chamber *D*.

In figure 70, you will see a schematic view of a throttle-operated accelerator pump. The base of the pump forms a part of the throttle-housing casting. A body fastened to this base carries an inner cylinder in which a piston operated by

the throttle through a lever and suitable linkage is fitted. The fuel enters the pump cylinder from fuel chamber *D* of the carburetor pressure regulator through a connecting passage and passes through the FILL-CHECK VALVE. The passageway from chamber *D* also supplies fuel to the space in the pump above and below the central body. At the side of the cylinder, and opposite the fill-check valve, is a port that connects through a second passage to the balance chamber at the outer left-hand end of the poppet valve of the pressure regulator. A second check valve is located in the diaphragm plate at the bottom of the cylinder. The operation of this type of accelerator is as follows.

When the throttle valve is closing, it moves the pump piston in the accelerator body to the top of the cylinder. This lowers the pressures in the cylinder, which causes the fuel from chamber *D* of the pressure regulator to push the check valve off its seat and fill the cylinder. At the same time, the valve at the bottom—or the relief check valve—is held tight to the seat by its closing spring. When the throttle is opened quickly, the pump piston moves downwards closing the inlet valve and driving the fuel out through the port on the opposite side. Since this port is connected to the balance chamber, the pressure of the fuel from the accelerator pump temporarily unbalances the diaphragm and causes a greater volume of fuel to be sent to the regulator discharge nozzles. The lower check valve of the accelerator pump is set to open at pressures of 35 to 40 pounds, and when these pressures are exceeded, fuel passes through the valve and into the chamber below the cylinder. This space is connected to the one above the cylinder by the passage shown in dotted lines, thus permitting the fuel to return to the inlet side of the pump.

The balance chamber is connected to the carburetor pressure regulator by a BALANCE CHANNEL at the top and bottom of the chamber. The pressure in the balance chamber eases off through these channels when the accelerator-pump operation ceases.

Since the accelerator-pump piston in both types of manual pumps is operated by the throttle, "pumping" the throttle

will normally result in discharging fuel into the blower section when the fuel pressure is up. However, with the single-piston type shown in figure 70, pumping the throttle will not discharge fuel into the blower section as long as the manual mixture-control is in the "idle cut-off" position.

DISCHARGE NOZZLES

A type of discharge nozzle used with the Stromberg injection carburetor is shown in figure 69. This nozzle is located directly in the air stream, and the space above the diaphragm is connected through a small tube and drilled passage to the air channel leading from the boost venturi to chamber *B* of the carburetor pressure regulator. The plunger valve rests on a seat above the fuel outlet. The charge spray is spread out evenly by a spherically shaped nozzle with drilled openings.

In another type of nozzle, known as the SPINNER NOZZLE (fig. 71), the fuel is induced into a hollow slinger hub in the supercharger rotor, whence it is thrown into the air stream by the centrifugal force created by the hub. This type of injection uses a constant-pressure nozzle as in the other type shown, but the assembly is much longer. It is mounted on the rear of the supercharger and extends through the main air passage to the special slinger hub on the supercharger rotor. The nozzle, which operates on the same principle as the one shown previously, is connected to the carburetor by an outside fuel line and has vent channels in the rear of the supercharger housing and the carburetor throttle body. When installing a nozzle of this type, be sure that the gaskets and shields between the carburetor-mounting flange and the engine are placed properly so that they do not obstruct the vent channels between the throttle body and the engine. Also be sure that the outside fuel tube is connected properly and that the joints are tight.

You will observe in the types of spray nozzle shown, that the chamber containing the nozzle valve-closing spring is connected to some point of the carburetor throat, the chamber thus being exposed to the pressure in the scoop or the boost

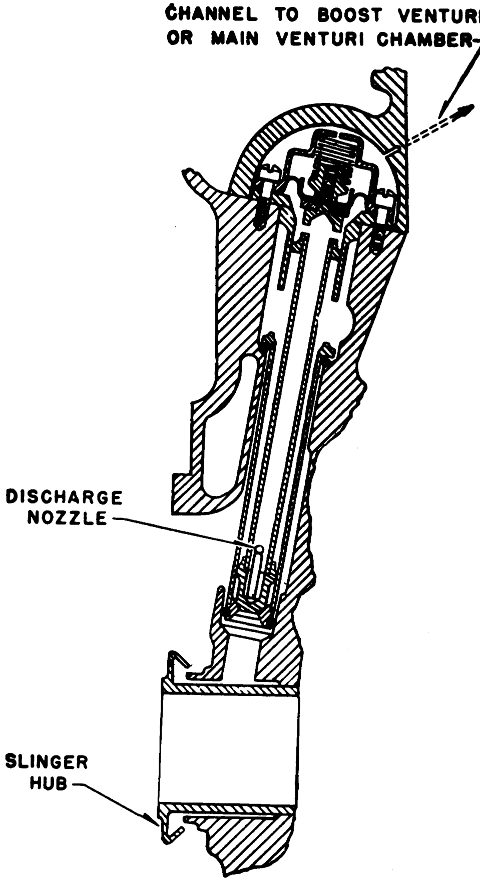


Figure 71.—Spinner type of fuel-discharge nozzle.

venturi, as the case may be. These connections lower the pressure in the nozzle-spring chamber as the engine speed increases, thus compensating for the increased pressure of the closing spring as the nozzle valve opens, and maintain an even movement of the valve. Experience with the spinner nozzle shown in figure 71 has disclosed that turbulent action results from having the spring chamber connected to the boost venturi. Result—the practice now is to plug up the opening to the boost venturi, and to make the connection to

the area around the main venturi, where the pressure is the same as in the scoop.

TYPICAL STROMBERG INJECTION CARBURETOR

The injection or pressure-type of Stromberg carburetor is designated by the first letter *P* or *Q*. The letter *Q* designates a smaller series than the *P* series, the former having a combined fuel-control and regulator unit. The other designations are the same as stated in connection with the float-type, except that the letter *R* after the *P* indicates a carburetor with a rectangular barrel.

The PT–13G5 model carburetor in figure 72, is typical of modern design, and, as the designation implies, has three barrels. It is of the downdraft type, with a fuel-head enrichment valve, automatic-mixture control, idle cut-off, throttle-operated accelerator pump, a spinner-type discharge nozzle, and a throttle balance. The air flow in the larger carburetors exerts so much pressure on the throttle valves that the valves have a tendency to "creep" shut, and a THROTTLE BALANCE is provided to counteract this tendency. The model illustrated also differs in other details of design from the basic type shown in figure 64. It has, for instance, two vapor vents and floats, one in the fuel screen chamber, and the other at the top of chamber *B*.

Both vents lead to the fuel tank. The PT–13G5 carburetor does not utilize an adapter but employs a spinner-type discharge nozzle that ejects the fuel directly into the blower.

The throttle balance is not shown in the outside view of the carburetor, because it is located at the rear end, or the end farthest from you in the illustration. There is a sectional view of the balance in figure 73. It has an arm that is pivoted at one end on a capscrew screwed into the carburetor casting. This arm carries a cylinder that is open at one end, and into which fits a sleeve or piston that is connected by another arm to the end of the throttle shaft. A coiled spring bottoms against both the inner sleeve and the outer cylinder, forming a cushion between these members that will resist any tendency of the throttle shaft to turn when it has been placed in a set position.

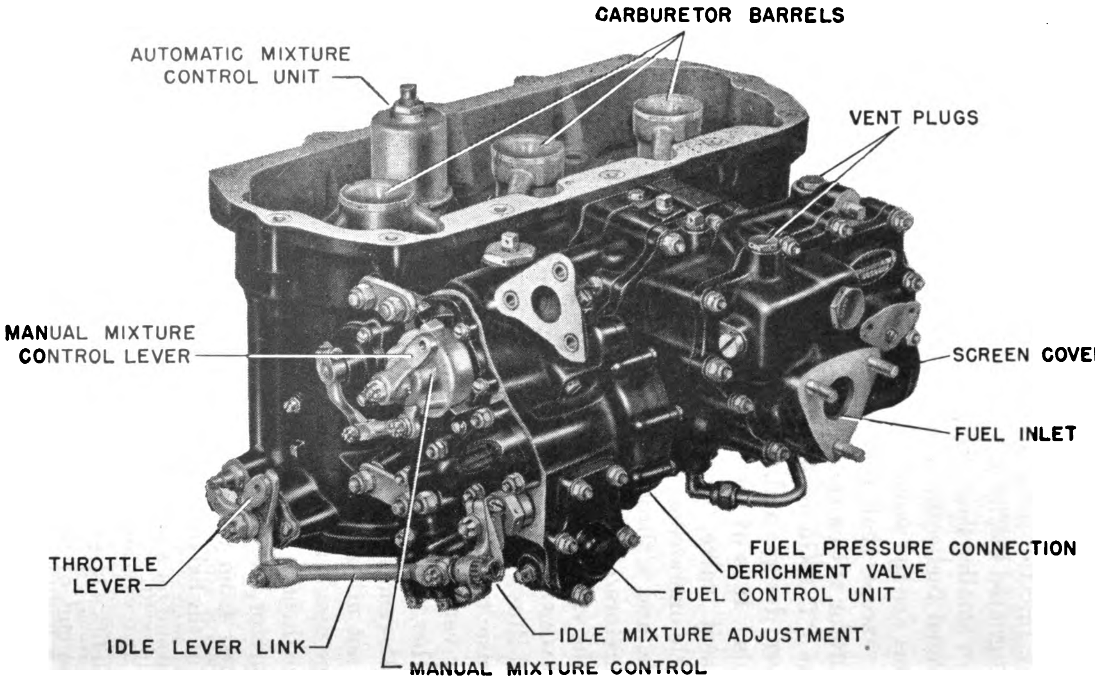


Figure 72.—Modern three-barrel Stromberg injection carburetor.

When installing carburetors of the PT–13G5 type on the engine, place the fuel inlet to the rear. Attach the fuel supply line from the fuel pump to the triangular pad on the cover of the rear body of the regulator by means of the three mounting screws. Connect a vapor-return line from the airplane fuel tank to the 1/8-inch pipe tap connection provided for this line near the top of the regulator. Another 1/8-inch pipe plug is provided in the rear body of the mixture regulator, which should be removed when connecting the fuel-pressure gage line to the regulator.

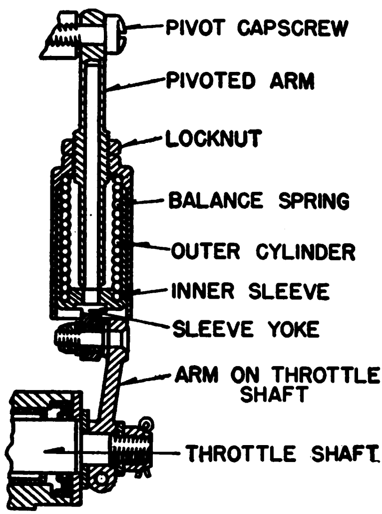


Figure 73.—Throttle balance.

The throttle lever of the carburetor has an 80° travel, and requires a control-rod movement of 2 9/16 inches. The manual-control lever has a 90° travel, a quarter circle, and requires a control-rod movement of 2 13/16 inches. Both of these levers may be shifted around radially on their shafts at 15° intervals, to bring them into the proper relation to the control rods, and to insure that they will have full travel in both directions. Sufficient space must be provided for the removal of the fuel strainer, and for access to the idle adjustment.

WATER-INJECTION SYSTEM

It is well known that Army and Navy aircraft engines are operated at MILITARY POWER with rich mixtures. It has been an established fact also that if the mixture could be "leaned-out" without a resultant detonation, or knocking, a considerable increase in power could be obtained.

It was determined that by properly injecting water into the induction system of the engine, the temperature of the fuel charge in the intake manifold was reduced, and the problem was solved.

When water is injected into the manifold, the total flow of fuel and water into the engine is approximately equal to that of the fuel alone which would be required to produce the same power in a larger engine not using water injection.

Emphasis is placed on the fact that the water-injection system is added to the engine to permit higher than military power under emergency conditions only. Operation under such conditions places an additional strain on the engine, and the operator must use the system with utmost discretion.

It is recommended that the water be applied only after the engine has been brought up to the military power. No harm will result, and the engine operation will not be affected detrimentally if the water is applied at powers as low as maximum cruising. But only a small amount of water will normally be carried in the airplane, and it should not be wasted at powers that can be obtained with fuel alone.

The water-injection system consists of a water tank, a water pump, a solenoid valve, a water-regulator unit, a fuel derichment valve and a supercharger regulator-reset mechanism. The function of each unit is outlined briefly as follows:

The WATER TANK carries the supply of water, which is sufficient to insure emergency power for a predetermined period of time.

The WATER PUMP, in some installations, is an electrically driven unit mounted near the water tank and controlled by a switch, marked PUMP SWITCH, in the cockpit. In other installations, the pump is mounted directly on the engine

and runs at all times when the engine is running. When the pump is in operation, it delivers the water to the solenoid valve. This valve is closed when the engine is operating under normal conditions.

The SOLENOID VALVE is located at the entrance to the water-regulator unit, and is also controlled by a switch—designated as the POWER SWITCH—in the cockpit. The purpose of the solenoid valve is to allow unmetered fuel to flow into the water-regulator unit. In some installations, the water pump and the solenoid valve are controlled by the same switch. This does not affect the functioning of either unit.

The WATER REGULATOR meters the water through the action of a poppet valve, which is controlled by unmetered fuel from the carburetor. This pressure is proportional to the airflow through the carburetor.

A FUEL-DERICHMENT VALVE is attached to or built into the carburetor (fig. 72). It begins to function as soon as water pressure builds up within the water regulator. The valve is operated by a diaphragm, and when water pressure is applied to the diaphragm, the valve moves endwise and closes one of the two economizer jets in the carburetor fuel-control unit. This reduces the fuel flow, and gives the leaner mixture necessary for the "best power" under emergency-power operation.

The supercharger regulator reset is also connected to the water regulator. The reset is diaphragm-controlled. When pressure is applied to the diaphragm by the water from the regulator, the supercharger regulator setting is changed so as to permit the high manifold pressure required for war-emergency power to be created.

The water-regulator unit is connected by a pipe to the fuel-feed intake, where the water mixes with the metered fuel from the carburetor. The mixture of fuel and water is then discharged into the intake air stream through the fuel-discharge spinner nozzle.

When the POWER SWITCH is turned off, the diaphragm of the supercharger regulator reset is returned by a coiled spring to its normal position, thereby resetting the regulator

to permit only normal manifold pressures. The derichment-valve diaphragm is also returned to its normal position by a spring when the water-injection system is no longer in use. This reestablishes the operation of both economizer jets, and provides the rich mixture required for military-power operation. The water-regulator unit also becomes inactive, and the check valve closes, preventing a reverse flow of fuel past the unit.

If the water injection system should fail because the water supply is exhausted, or the water pressure becomes too low, the various units in the system will return to normal, just as though the POWER SWITCH were turned off.

OPERATING INSTRUCTIONS FOR STROMBERG INJECTION CARBURETORS

The description of the operation of the Stromberg injection carburetor, just completed, shows that this type differs radically from the float type in that it does not have a vented float chamber, but instead, has a closed fuel system from the fuel pump to the discharge nozzle. It has already been explained that fuel is prevented from leaking into the engine by the spring-controlled needle valve in the discharge nozzle, which is closed when the nozzle fuel pressure is less than 4 p. s. i. Even though the fuel pressure should exceed 4 p. s. i., with the throttle closed and the engine standing still, the fuel can flow only at the lowest idling rate. When the idle cut-off is in use it reduces the flow to considerable less than the idle flow. Since the system is of the closed type, it remains full when the engine is stopped by cutting off the fuel flow with the idle cut-off.

When filling the fuel system, and starting or stopping engines equipped with an injection carburetor, use the following procedure.

If the carburetor has been drained, or is being used for the first time after installation on the engine, it must be filled up first, which should be done as follows:

Open the fuel valve of the tank.

Set the mixture-control lever at AUTO RICH, and open the throttle valve about halfway.

Operate the auxiliary fuel pump to raise the fuel pressure to 5 p. s. i. Then continue to operate the pump slowly until a small amount of fuel runs from the supercharger drain.

NOTE.—When the engine is not running, the rate at which fuel may enter the second regulator and the fuel-control body—this fuel being metered—is held to idling rate, causing the carburetor to fill slowly. The rate will be the greatest when the throttle is open beyond the idle position. In operation, there are no vents in the system beyond the float-operated vapor separator. All entrapped air must escape through the nozzles, which will sometimes cause the engine to stop after being started. If trouble of this kind is experienced, remove the vent plug from the second chamber of the mixture regulator, and work the auxiliary pump until the fuel stands level with the plug opening.

STARTING ENGINE

The method of starting a cold engine by priming is explained under ELECTRIC PRIMERS. The following procedure should be followed when starting warm engines—temperature above 60° F. or 15° C.—equipped with direct-cranking starters, or on all engines, warm or cold, on which primers are not provided.

Set the mixture control in the IDLE CUT-OFF position, with the throttle lever placed so as to give a speed of approximately 1,000 r. p. m.

Operate the auxiliary pump until the fuel pressure is approximately 10 p. s. i., turn the ignition switch on, and engage the starter. As the engine starts to turn, move the manual mixture-control out of the IDLE CUT-OFF position and into the AUTO-RICH position. Continue to operate the auxiliary fuel pump slowly to assist the engine fuel pump to build up pressure. If the engine does not start in two or three revolutions after moving the mixture-control to AUTO-RICH, move the control back to the IDLE CUT-OFF position, so that the engine will not be flooded during the cranking operation.

NOTE.—Remember that the fuel is being discharged from

the carburetor discharge nozzle at all times when the mixture-control is out of the IDLE CUT-OFF position, and the fuel pressure is over 4 lbs. p. s. i. Operating the throttle does not discharge fuel to the engine. The engine can be started with the throttle lever in any position. If the engine loads up, place the mixture-control lever in the IDLE CUT-OFF position, open the throttle, and crank the engine. If the ignition is left on in this process, be ready to close the throttle and move the mixture control to AUTO-RICH, when the engine fires. If a "flooded" engine is being cranked by hand to clear it be certain that the ignition is off.

IDLE ADJUSTMENT

An excessively rich idle setting causes incomplete combustion of the mixture in the cylinders of an engine. This results in the formation of soot which, when combined with oil that passes the piston rings, forms solid cakes—similar to the somewhat familiar briquets made from coal dust and oil. This carbon soot, bonded to the spark plugs and piston-ring grooves by the oil and heat of combustion, soots the spark plugs and causes sticking rings. The obvious remedy is to prevent the formation of soot by idling the engine with a clean-burning mixture—such as a "best-power" mixture—or one slightly leaner.

Good acceleration sometimes demands a mixture slightly richer than best power, especially in cases where the capacity of the accelerating pump is marginal—that is, just giving the minimum degree of acceleration required. However, the mixture should never be so rich as to cause the r. p. m. to drop off more than two percent from the maximum r. p. m. obtainable with any other adjustment of the mixture at the same throttle setting.

Navy specifications require that service aircraft engines be capable of idling at 600 r. p. m. with exhaust stacks, or at 450 r. p. m. with exhaust collectors. A low idle r. p. m. is necessary for proper control of airplanes taxiing on water and for reduction of wear on brakes and tires of land type airplanes.

In many instances, engines have been found operating with idle mixtures so rich that an excessively high idle speed was required to prevent fouling of the spark plugs. Other cases have been found in which the idle mixture was adjusted so lean as to cause faulty acceleration. If the carburetor is adjusted properly, the engine will idle at the required MINIMUM r. p. m. for at least 5 minutes with no signs of fouling. Acceleration will also be satisfactory under these conditions. However, you must remember that clean spark plugs and correct adjustment of the valves and ignition, as well as tightness of the induction system between the carburetor and the cylinders, are necessary for satisfactory idling.

CORRECT IDLE ADJUSTMENT is highly important. The following procedure is recommended for setting the idle on any aircraft carburetor:

Warm-up the engine in the usual manner until the oil and the cylinder-head temperatures are normal.

Check the magnetos. If r. p. m. "drop-off" is excessive, check for fouled spark plugs. If drop is normal, proceed with the idle adjustment.

Close the throttle to give an idle speed of approximately 600 r. p. m. If the r. p. m. increases appreciably after the change in the idle-mixture adjustment during the following steps, readjust the throttle stop to restore the desired r. p. m.

When the speed has stabilized, move the cockpit mixture-control lever momentarily—but with a smooth, steady pull—into the IDLE CUT-OFF position (AUTO-LEAN is sufficient for some Stromberg carburetors) and note the tachometer for any changes in r. p. m. during the process of leaning. Be sure to return the mixture control to the AUTO-RICH position before the r. p. m. drops so low that the engine will cut out. An increase of more than 10 r. p. m. while "leaning-out" indicates an excessively rich idle adjustment. An immediate decrease in r. p. m. (not preceded by a momentary increase) indicates a too-lean idle adjustment.

If the preceding two steps indicate a too-rich or a too-lean idle adjustment, turn the idle adjustment one or two notches in the direction required for correction, and check the new position as described in those paragraphs. Make additional readjustments as necessary until a check with steps 3 and 4 results in a momentary "pick-up" of approximately 5 r. p. m.—never more than 10 r. p. m.

Finally, adjust the throttle stop to obtain the desired r. p. m. with closed throttle.

The method described should give a setting that will obtain maximum r. p. m. with minimum manifold pressure. In case the setting does not remain stable, check the idle linkage. Any looseness in the linkage will cause erratic idling because a movement of the throttle will not produce the same movement of the idle needle.

Keep in mind the fact that when the idling is adjusted as described on engines having the original factory adjustment, the adjustment may not be permanent. The reason for this is that the carburetor diaphrams will be stiff, since they have not had sufficient opportunity to become flexible through soaking in gasoline. After a few days of running, the diaphrams will soften and become too flexible. The mixture will then tend to become too rich, as will be evidenced by black smoke from the exhaust. The idle setting must then be readjusted to obtain a proper idle mixture with a low engine-idle speed.

In all cases, you must make allowance for the effect of weather conditions upon idling adjustment. The relative position of the airplane with respect to the direction of the prevailing wind will effect the propeller load and its r. p. m. Hence, you will be wise to make the idling setting with the airplane crosswind. The idle adjustment will be affected also by the condition of the day, whether hot, moist, or cold.

Once an idle adjustment is made properly as described here, subsequent adjustments should not be necessary except to correct for wide variations in weather conditions.

In case you should find the idle-mixture adjustment has insufficient travel to obtain the correct idle mixture, discon-

nect the idle link—take a look at the idle adjusting-mechanism, figure 74, from the screw eye by removing the link bolt. Then screw the eye into the threaded bushing if leaner mixtures are required; or screw it out of the bushing if richer mixtures are desired. One revolution of the screw eye is equivalent to approximately 13 notches of the adjusting screw. Reconnect the idle link with extreme care to make certain that the various parts are in their correct positions. See that the four plain washers are placed inside and outside the idle link, as shown, and place the spring wave washer in position carefully so that it will fit over the outside diame-

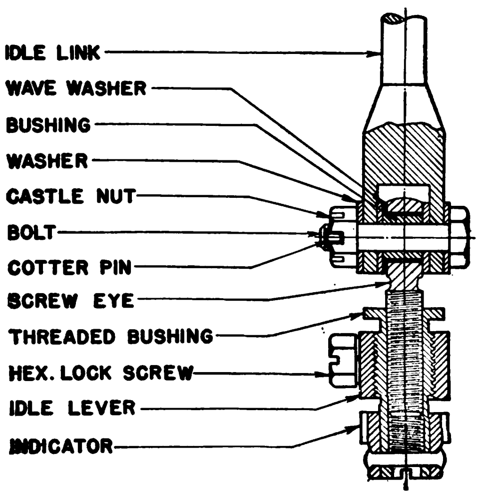


Figure 74.—Section through idle-adjustment mechanism.

ter of the bushing, and be next to the screw eye. The castle nut—a type of nut provided with slots through which a cotter pin passes to lock the nut on its stud or bolt—must be tightened enough to allow the yoke of the idle link and the plain washers to clamp the bushing, so that it cannot move on the bolt. Otherwise, clearance between the inside diameter of the bushing and the bolt may allow play in the linkage to cause inconsistent engine idling.

When the idle is adjusted properly, tighten the idle mixture-adjustment lockscrew and safety wire it in position.

STOPPING THE ENGINE

To stop an airplane engine equipped with a Stromberg injection carburetor, move the mixture control to the IDLE CUT-OFF position with the engine running at about 80 r. p. m. When the engine stops, turn off the ignition. This will give a clean cut-off without after-firing. It should be noted that with this type of carburetor, moving the mixture-control lever to the IDLE CUT-OFF will stop the engine at any speed or throttle position. Stopping the engine by shutting off the fuel-tank valve is prohibited, because vapor may be pumped into the regulator. Keep the fuel-tank valve closed when the engine is not being operated.

MINOR ADJUSTMENTS AND CHECKS

Stromberg injection carburetors are designed for accurate adjustment and uniform performance. Complete overhaul can be performed only with the aid of special tools and testing equipment. The exactness of their performance requires that they never be changed by guesswork, and once they are set and lock-wired, nothing should be tampered with that will alter the functioning of the carburetors. In more simple language, DO NOT TINKER WITH THE CARBURETOR.

There are several processes that may be performed to assure proper action of the carburetor, and which may be safely done on the spot. You will find such points outlined as follows:

Remove the strainer bolt, cap, and the strainer, and clean the parts thoroughly. Then inspect the vent floats, and the needle valves and their seats.

In reassembling the parts, be sure to place the strainer housing with the recessed end (into which the spring fits) toward the outside, or housing cover.

Drain any fuel that may have collected in the air chambers, by removing the drain plugs in the bottom of the regulator. The presence of the fuel in the air chambers indicates that a sealing diaphragm is leaking.

MIXTURE-CONTROL AND IDLE LINKAGE

Occasionally examine the joints in this linkage for play.

Tighten the link bolts to prevent looseness in the joints, and make sure that the wave spring washer is in place.

Do not disassemble any other parts except when the carburetor is functioning badly, in which case, you should remove it from the engine.

GENERAL NOTES

Be careful not to cut the neoprene packing with the edges of the tube when you have occasion to remove the large fuel line running from the fuel-control unit in the spray nozzle. If the material is chipped, the pieces may lodge under the injector spray needle and prevent its closing.

Never use compressed air to blow out carburetor or assembled units as damage to diaphragms may result.

When a carburetor must stand idle for some time—over 10 days—drain it thoroughly, and then flush it with an approved lubricating oil. Many oils contain agents that have detrimental effects on the carburetor diaphragms, and are not approved for flushing diaphgram-type carburetors.

Under no circumstances permit the flushing oil to come in contact with the main or boost venturi surfaces, with the impact tubes, or with the AUTOMATIC MIXTURE-CONTROL UNIT. Make sure, however, that all fuel chambers in the discharge nozzle and in the accelerator pump are filled with the oil.

Flushing oil picks up gasoline in the flushing process. The oil should, therefore, be discarded after having been used a maximum of five times.

Drain the flushing oil thoroughly from the carburetor, and plug all fuel or drain outlets.

PRESSURE-REGULATOR POPPET VALVE

Inspect the poppet valve after removing the valve cover. Check to see that it has full movement and is not leaking, and move it by hand while looking for grit on the valve seat. Measure the complete travel of the valve. Do not attempt adjustments on this unit without a flow bench.

SPRAY NOZZLE

The nozzle is not readily accessible except when it is on

the outside of the adapter, in which case you can remove and clean it. If the spray valve does not close tightly, it will seriously interfere with the running of the engine at altitude, causing flooding and rough operation.

MANUAL MIXTURE CONTROL

Examine the manual mixture-control plate by removing the complete cover and latch assembly. Be careful not to lose the valve spring during this operation. If trouble is indicated in the latch mechanism at the end of the mixture-control shaft, you should disassemble it and inspect the parts. When reassembling, apply a coating of grease between the plates. A tight seal is necessary between the plates. Looseness affects the IDLE CUT-OFF.

AUTOMATIC MIXTURE CONTROL

You can remove the automatic control unit for inspection and replacement by unscrewing the entire assembly from the throttle unit. When there is no exchange available, your only recourse in case of trouble with this device is to disassemble it, clean it thoroughly, and reassemble for immediate use. During this process be very careful not to change the position of the adjusting screw and locknut. See figure 58.

ELECTRIC PRIMER

The Stromberg electric primer is used on most engines of 2,000 cubic inches displacement, and may be used on smaller engines. Its purpose is to control a supply of gasoline directly to the engine manifold to make starting easier. The primer is mounted on the rear body of the injection carburetor fuel regulator in place of the regular poppet-valve cover. The manner of mounting the primer and the method of connecting it into the electric circuit are shown in figure 75. Provision is made in present production for installation of the primer. This means that the pressure-regulator housing is drilled for the primer inlet, and that the necessary longer studs are employed as regular equipment. If the

studs are too short, you will have to replace them with longer ones.

To make the installation, proceed as follows. Remove the poppet valve cover from the rear body of the carburetor pressure-regulator unit. If the cover is fastened by short studs, replace by longer ones—part number 392831. Also see that a hole is provided for the fuel hole in the primer base in the gasket used to seal the primer. New gasket, part number 392372, has such a hole. Place the primer on the regulator at a 30-degree angle, which will bring it approximately in the position shown in figure 75, and fasten it with

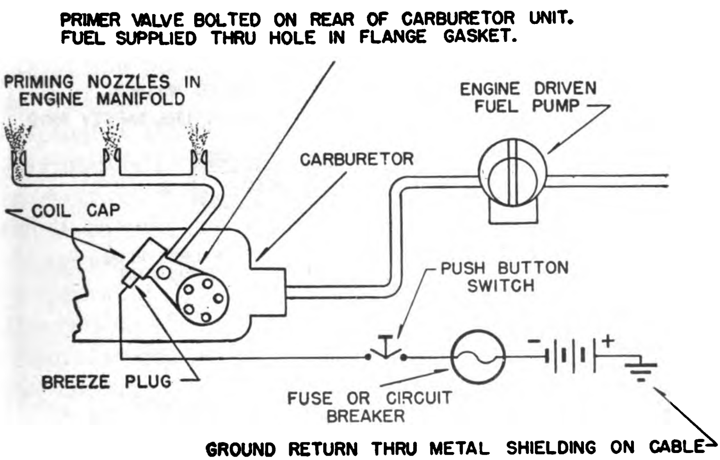


Figure 75.—Electric primer, method of mounting and connecting into the system.

elastic stopnuts. Connect the outlet of the primer to the fuel outlet tube, and run it to the primer nozzles as recommended by the engine manufacturer.

You will be able to understand the operation of the electric primer by looking over the sectional view in figure 76 carefully. A special connector—called a Breeze plug connector—is designed to be grounded to the shielding on the cable, since grounding through the primer-valve body is not dependable. The shielding serves as the return circuit for the system.

A GROUNDED-RETURN CIRCUIT is simply a circuit which employs parts of the carburetor, engine, etc., in place of a separate return cable. It has no particular advantage outside of its simplicity, but will give satisfactory results as long as there is a good metal-to-metal contact at all points.

The negative lead, figure 75, from the battery is connected through a push-button switch in the cockpit to the central terminal of the Breeze plug. The coil cap may be rotated within a 220° range to bring the Breeze plug in the most advantageous position for making the connection.

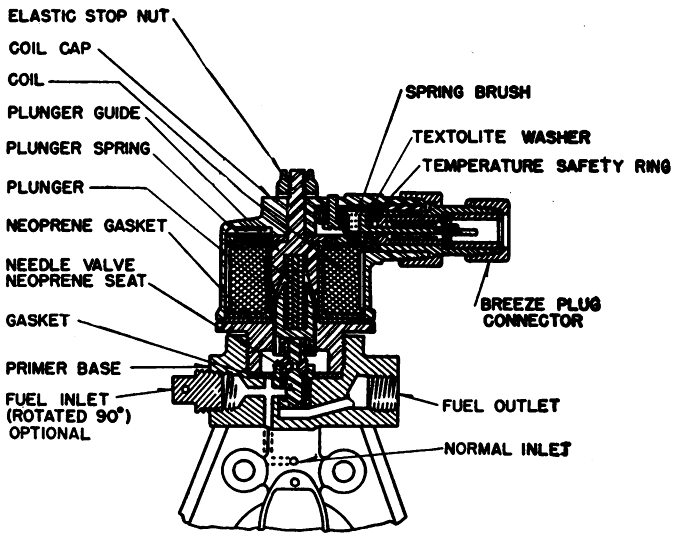


Figure 76.—Cross-sectional view of Stromberg electric primer.

The primer valve is available for operation with either 12 or 24 volt electrical systems. It will operate at nominal voltage ratings under pressures of 15 p. s. i., to 45 p. s. i. The voltage at the solenoid, or coil, terminal may vary from 8 to 13 volts on the 12-volt circuits, and from 14 to 28 volts on 24-volt circuits, under a pressure of 15 p. s. i.

The operating voltage—that is the voltage at the primer terminal—should be kept as close to the normal value as possible, which means that the proper size and length of cable should be used in connecting the primer into the circuit

to avoid voltage drop, or loss. For instance, a 20-foot length of No. 20 B. and S. gage wire will cause a loss of 1.5 volts with a 12-volt battery, while the same length of number 16 B. and S. gage wire will deliver 11.7 volts at the primer terminal, at a loss of only .3 of a volt.

The switch used in the primer-coil circuit should be of the push-button type to help prevent over priming. A fuse ring is placed inside the primer cap to prevent overheating of the coil in case the circuit is kept closed for too long a time. The melting of the fuse "shorts" the circuit, thus protecting the coil. A second fuse, or circuit breaker, must be provided in the battery circuit to open the circuit when the fuse ring in the primer causes a short.

And now back to the sectional view, figure 76. With the engine stopped, fuel may be drawn from the fuel tanks and supplied to the primer valve through the carburetor at approximately 15 p. s. i. by the auxiliary pump—either wobble or electric. When the push button in the primer circuit is closed, current passes through the primer coil and produces a magnetic field that draws up the movable plunger, which carriers at its lower end a needle valve with a neoprene tip. The raising of the valve from its seat opens the channel between the inlet and outlet of the primer, and permits fuel to pass through the primer to the priming nozzles in the engine manifold.

HOW TO USE PRIMER

To prime the engine with the electric primer first build up pressure by the auxiliary pump with the carburetor mixture control set in the idle cut-off position, and the throttle lever set to give an engine speed of about 1,000 r. p. m.

Prime the engine by closing the push-button switch for several seconds, or according to your previous experience on the engine. The time required depends upon the engine temperature. If the engine is hot, priming may not be necessary.

Next engage the engine with the ignition switch on, and when it fires, move the mixture control to automatic rich (auto rich) and use the auxiliary pump slowly to aid the

engine to build up pressure. Then turn the primer switch on and off as necessary to keep the engine running until it warms up.

Follow the engine manufacturer's instructions for other starting operations.

QUIZ

1. (a) "Decode" the carburetor designations NA—Y9C and PT—13E2.
   (b) In each case, what would be the actual size of the carburetor barrel?
2. What are the units in an injection carburetor?
3. (a) In large carburetors, what is the effect of the airflow on the throttle valves?
   (b) What mechanism is designed to compensate for this?
4. By what two means does a water-injection system make it possible to operate the engine at higher power?
5. Is the failure of the water-injection system apt to be dangerous? Why?
6. The factory adjustment on the idling system of an injection carburetor isn't necessarily permanent. Why?
7. Why is the strainer chamber vented?
8. What precautions must you take when installing a spinner-type nozzle?
9. What idling specifications does the Navy require injection carburetors on service aircraft engines to meet?
10. The number of barrels in an injection carburetor is governed mainly by the -------------------- of the engine.
11. The letter "D" in the model designation indicates ----------------.
12. A particular feature of the Stromberg injector carburetor is that --------------------.
    a. little fuel is discharged into the venturi.
    b. no fuel is discharged into the venturi.
    c. some fuel is discharged into the venturi.
    d. fuel discharged into the venturi is a highly rich mixture.
13. The idle cut-off position is at the extreme limit of travel of the manual-control lever in a -------------------- direction.
14. When installing PT–13G5 carburetors, place the fuel inlet --------------------.

15. It is recommended that, when using a water injection system, the water be applied _____________________.

a. as the engine is being brought up to emergency power.
b. When starting to bring the engine up to emergency power.
c. after the engine has been brought up to emergency power.
d. none of the above.

16. The engine can be started with the throttle lever in _______________.

17. To stop an airplane engine equipped with a Stromberg injection carburetor, move the mixture control to the idle cut-off position with the engine running at about __________ r. p. m.

a. 600.
b. 700.
c. 800.
d. 900.

CHAPTER 9

TESTING AND MAINTENANCE

STROMBERG FLOW BENCH

The Stromberg injection carburetor, as has been impressed on you from the start, is a precision instrument, and must be overhauled only by trained personnel having the special tools and test equipment necessary to repair and adjust the carburetor properly.

When the carburetor has been overhauled, it should be set up on a testing instrument, known as a flow bench, and adjusted to data furnished which will reproduce the exact conditions under which the carburetor will operate in place on the engine. After proper adjustments and checks are made on the flow bench, the carburetor is ready for test flight in an airplane. Runs or readings on an engine test stand are not necessary. Before starting a test on a flow bench, you should have at hand the carburetor-setting specification sheet and flow-test limits sheet, both of which contain information on the correct sizes of variable parts, settings, and flow limits for the carburetor as it is applied to a certain engine. Without this information, the test would be of little value, because there is nothing to be gained by making a test if you do not know exactly what results should be obtained.

Carburetor-setting specification sheets and other data may be obtained from the carburetor manufacturer's manuals, or from Naval Aeronautical publications.

The flow bench is designed for duplicating the effects of engine operation on the regulator and fuel-control units of the injection carburetor, and cannot be used for testing conventional types of carburetors. The metering pressures across the jets in the fuel-control unit of the injection car-

buretor are controlled by the regulator unit of the carburetor. As previously explained, the pressure-regulator unit is actuated by venturi suction and the impact pressure resulting from airflow through the throttle body.

The airflow and the corresponding venturi suction and impact pressure are recorded for each engine-operating condition, from an actual run on a test engine. These records are placed on the specification sheets for the engine and carburetor. If the venturi suction and the impact pressure corresponding to a given airflow are imposed on the regulator unit of the injection carburetor, the volume of fuel flowing from the metering jets will be exactly equal to that which would flow from the metering jets if the carburetor were attached to an engine with the corresponding volume of air flowing through the throttle body.

Briefly, this means that if the same conditions of suction and pressure can be imposed on the carburetor artificially as when it is in place on the engine, then the carburetor can be tested satisfactorily independent of the engine. And that is exactly what is done on the flow bench. Instead of having air actually flowing through the throttle body—as would be the case with the carburetor on the engine—the corresponding values of suction and impact pressure which produce the same effect as the airflow, are employed in the test.

It was explained that the air section of the regulator unit, figures 64 and 68, is divided into a SUCTION CHAMBER and a SCOOP-PRESSURE CHAMBER by a diaphragm. The pressure difference between the two chambers acting on the air diaphragm, produces the AIR-METERING FORCE. To avoid the necessity of regulating both suction and pressure on the diaphragm during a carburetor test on a flow bench, a value of suction alone equal to difference in pressure between the two chambers is applied to the suction side of the diaphragm. The other side has a vent open to the outside air, so that it is always at atmospheric pressure.

An injection-carburetor test on the flow bench consists of applying a value of suction to the pressure-regulator unit corresponding to an airflow for each engine operating con-

dition, and measuring the resulting fuel flow from the metering jets. The fuel-air ratio—usually written F/A—is the ratio of the number of pounds of fuel flowing from the metering jets, to the number of pounds of air corresponding to the value of the suction applied to the suction chamber of the regulator unit.

Suction values and fuel volumes per unit of time for testing each injection carburetor are recorded from a test run of that model carburetor on the particular engine for which it was designed, and these are placed on the INJECTION CARBURETOR FLOW-BENCH TEST SHEET for that carburetor.

The flow bench used for testing Stromberg injection carburetors consists of equipment that will supply a source of regulated suction, a fuel supply that will maintain fuel delivery to the carburetor under the required pressure, manometers—gages for measuring the pressure of gases and vapors, and gages for measuring the fuel flow through the carburetors.

By means of the flow bench, a simple, definite, and accurate check can be obtained on the performance that the injection carburetor will give under flight conditions, and the carburetor, as has been stated, can be installed on an engine ready for flight without additional tests on a torque stand.

PRECAUTIONS IN USE OF FLOW BENCH

Danger always lurks in the presence of gasoline or other flammable vapor. Since a flow bench is employed to test carburetors in which gasoline has been used, and normal heptane is used in the test, the danger of disastrous explosions, fires, and personnel injuries always exists. To avoid such trouble, do not use fixtures, motors, fans, radios, hot plates, unit heaters, flashlights, etc., that are not of the explosion-proof type and approved by the Insurance Underwriters or the Navy Department.

The flammable vapor is heavier than air, and therefore is more likely to accumulate on the floor of the test room. Exhaust fans—of the approved type, remember—will do much to prevent such accumulation. If the room is open, such pre-

caution will probably not be necessary, but, in cold climates, when the room must be kept closed, some form of artificial circulation is necessary.

Of course, it is recognized that war sometimes creates emergency situations in which some safety precautions are impossible, but this is no excuse for laxity and for slighting possible safety measures. Aside from the personnel-injury element involved, the need for precaution in the field is more urgent than at supply bases, because of the difficulty—or even impossibility—of replacing damaged equipment.

Always provide fire-extinguishing equipment in a room where the flow bench is installed. The ideal installation is the fully automatic carbon-dioxide (CO_2) fire extinguishers on and around the bench. Such equipment requires 100 pounds of CO_2 available to the automatic switch apparatus and the flow bench. Provide for the distribution of gas at five points at least on top of or beneath the flow-bench table. When such equipment is not available, have CO_2 hand extinguishers convenient to the bench—not less than one 50 pound unit for each bench being essential. The 30-pound type of extinguisher is recommended, with a minimum of three units per bench.

In order to operate efficiently, the flow bench must be installed properly in the first place. and then be inspected periodically to insure that it is kept in satisfactory working order. Install the bench on a solid foundation in a dry, well-lighted area. Allow a minimum clearance of 2 feet at either end and behind the bench to provide room for making adjustments. Use a gasoline-proof compound, such as litharge, on all iron-pipe threads.

ADDITIONAL SAFETY PRECAUTIONS

A final word of warning. Since the flow-bench room is filled with gasoline and heptane fumes, all electrical connections must be made explosion proof. Every precaution must be taken to protect the operator. Install an explosion-proof safety, emergency, switch between the motor-control switch and the source of power, in order to allow service on the

motor or motor control without danger of fire. The motor control is not sealed when it comes from the factory, and you should seal it with gasket compound after the connections have been made inside to the source of power. Take precautions to prevent dangerous fumes from passing from the flow-bench room through conduits and other passageways to some unprotected part of the building. This is usually taken care of by a Y-connection in the conduit being filled with a sealing compound on both sides of the switch.

CHECKING CARBURETOR BEFORE FINAL REASSEMBLY AND INSTALLATION

When the carburetor has been given a bench test and all adjustments have been made properly, there remains a final checking of the carburetor before installing it on the engine. Remember that no matter how successful the bench tests might be, a careless oversight on your part will cause untold damage. Therefore, make a habit of asking yourself such questions as the following, before installing the carburetor:

1. Is the enrichment-valve adjustment properly safetied, and is the entire assembly safetied to the casting?
2. Is the poppet valve of the pressure control properly safetied?
3. Have I locked the idle-spring adjustment? Is the acorn nut installed and safetied, and is the proper seal used beneath the acorn nut?
4. Have I removed the plugs from the booster venturi? (Don't overlook this.)
5. Have I removed the masking tape from inside the carburetor barrel?
6. Have I removed the blank mixture-control bleed, and installed the correct bleed? (Don't let this one elude you.)
7. Have I inspected the entire unit to make sure that all nuts, bolts, and plugs are properly installed and secured?

TROUBLE SHOOTING

It is obviously impossible to suggest here all of the possible

causes that could affect the operation of an airplane engine. The object of this section is to provide a check procedure that will enable you and other mechanics to determine, if possible, the sources of many troubles without removing or completely dismantling the carburetor. The method of procedure in eliminating troubles must, of course, be determined by the engine-operating symptoms, with which you will gradually become familiar by experience. Remember that symptoms such as improper idle, poor acceleration, and lack of power, often do not originate in the carburetor or fuel system. The trouble may be in the engine, and it will be necessary for you to consult the instruction manual issued by the engine manufacturer in order to determine the cause.

The first step in locating the cause of defective carburetor operation is to check the specifications and setting, to make sure that these conform to the make and model of the engine on which the carburetor is installed. If the carburetor settings appear to be the correct ones for the engine, do not change carburetor setting or specification without approval of the engineering officer, or until complete information is available regarding effect of change on mixture ratio and engine operation. Do not, at any time, change carburetor adjustments until unsatisfactory engine operation has been definitely established as a result of improper carburetion.

If an ENGINE EQUIPPED WITH A STROMBERG INJECTION CARBURETOR WILL NOT START OR CONTINUE TO RUN AFTER STARTING, check the following items:

Engine not being started properly. Read again instructions for starting, as given under ELECTRIC PRIMER.

Fuel pressure insufficient. If gage indicates proper pressure, check the gage.

Idle adjustment is too rich or too lean. Readjust idle valve.

Air in pressure-regulator unit. Remove the vent plug in the unmetered fuel chamber, figure 64, of the regulator unit, and pump fuel until it stands level with the plug opening. Check the position of the manual mixture-control to see that it is not set in the IDLE CUT-OFF POSITION.

Main-discharge nozzle sticking open. Check to see that the nozzles will hold a 3 p. s. i. pressure without discharging fuel. Otherwise, fuel will boil under a high vacuum and give an erratic metering.

If the engine runs too rich or too lean at cruising power, look for one or more of the following causes:

Low pressure on fuel. Check the fuel pump and the fuel-pressure gage. Clean the fuel strainer if the pressure will not rise.

Foreign material in the automatic-lean metering jet.

Automatic mixture-control unit defective. Check the unit setting and also the bellows if the carburetor is running rich or lean in the automatic position when operating above sea level.

If the engine runs too lean at take-off or rated power but satisfactorily at cruising power, check for insufficient fuel pressure.

When the engine runs too lean or too rich at altitude in automatic position, but satisfactorily at sea level, make a check of these points:

Vapor-separator float needle in unmetered fuel chamber stuck in closed position. Remove the strainer, and inspect the float for free movement.

Automatic mixture-control unit set incorrectly or not functioning properly. Remove the unit from the carburetor, and check travel of the needle, and readjust if necessary. This requires special equipment which is described elsewhere in this book.

Manual mixture-control valve set in wrong position. Check the linkage to the control lever carefully.

Emergency full-rich valve plates open or leaking. Remove the valve cover on the throttle body and see that the slots in the plates are open in the full-rich position and that plates do not leak.

If the engine does not accelerate properly, but runs satisfactorily with slow throttle movements, look for the following causes:

Accelerator pump not adjusted to give the required travel. The remedy is obviously to readjust the pump.

Fuel inlet to the accelerator pump clogged at the intake restriction—if of the diaphragm type—or at the inlet valve channel—is of the throttle-operated type. Remove the pump cover and diaphragm, or pump body, and examine carefully.

Discharge nozzle leaking. See previous comment relative to nozzle sticking open.

Fuel leak into air chamber in regulator unit. Remedy by removing the drain plug from the air chamber. If the accelerator pump is of the diaphragm type, the suction hole to the air side of the diaphragm may be closed. Check to see that the holes line up correctly.

If the engine continues to run with control lever in idle shut-off position, check the fuel mixture regulator for proper operation.

QUIZ

1. (a) What is the general procedure by which an injection carburetor is tested on a flow bench?
   (b) If the carburetor passes the flow bench test, what further tests must be made on it before it is ready for test flight on an airplane?
2. (a) Why should the flow bench test room be well ventilated?
   (b) What is the most dangerous part of the room in this respect? Why?
3. What is the first step in checking up on a carburetor which is not operating properly?
4. After the proper adjustments are made on the flow bench, the carburetor is ready for ______________.
5. Fuel-air ratio is usually written ______________.
6. Always provide ______________ in a room where flow bench equipment is installed.
7. The flow bench motor should be sealed with ______________ after the inside connections have been made.

8. When the final check is made on a carburetor, be sure to remove all but the ______________.
   a. masking tape from inside the carburetor barrel.
   b. acorn nut.
   c. plugs from the booster venturi.
   d. blank mixture control bleed.
9. Do not change carburetor adjustments until unsatisfactory engine operation has been definitely established as a result of ____________________.
10. When the Stromberg injection carburetor has been overhauled, it should be adjusted on a ______________.
11. The flow bench ______________ test conventional type carburetors.
12. All equipment used around a flow bench should be ______________ proof.
13. Allow a minimum clearance of _________ feet at either end and behind the bench to provide room for making adjustments.
   a. 2.
   b. 4.
   c. 6.
   d. 8.
14. When the final check is made on a carburetor, inspect all but ______________ to see if they are safetied.
   a. enrichment-valve adjustment.
   b. pressure control puppet valve.
   c. blank mixture-control bleed.
   d. the acorn nut.
15. The first step in locating the cause of defective carburetor operation is to check the ______________.

CHAPTER 10

AIRCRAFT-ENGINE INDUCTION SYSTEM

THE WORD "INDUCTION"

The word "induction" is the name applied broadly to the devices and accessories that are used to supply fuel to the airplane engine, and which are affected by the suction produced by the downward strokes of the engine pistons. This system includes such items as the air scoop, the carburetor air preheater, the carburetor, the manifolds, the diffuser, and the supercharger. However, since the other parts have been described previously, only the diffuser and the supercharger will be discussed in this chapter.

SUPERCHARGING

The power that an airplane engine develops will vary in approximate proportion to the pressure of the air entering the cylinders. The pressure of the atmosphere varies at different altitudes. Table 2 gives the readings at certain altitudes as recorded by a pressure gage.

Table 2.—ATMOSPHERIC PRESSURE IN POUNDS PER SQUARE INCH (P. S. I.) AT DIFFERENT ALTITUDES

Altitude in Feet	Atmospheric Pressure (P. S. I.)
Sea Level	14.7
6,000	11.08
8,000	10.92
10,000	10.11
20,000	6.75
25,000	5.45
30,000	4.36
35,000	3.46

From the table, you will observe that the atmospheric pressure at 10,000 feet is a little more than 5/8 than at sea level;

at 20,000 feet slightly less than ½; and at 35,000 feet, approximately ¼. At these reduced pressures, a cubic foot of air will weigh considerably less than a cubic foot of air at sea level. This reduction in weight for a unit volume of air with an increase in altitude reduces the volumetric efficiency of the fuel mixture—the volume of fuel taken into the cylinders—and hence the power output of an engine. The reduction in volumetric efficiency can be offset by increasing the pressure of the air before it goes to the cylinders, and this is done in airplanes by using a supercharger.

A supercharger is simply an air pump. It requires a certain amount of power from the engine for its operation. Superchargers are designed to give a pressure at the cylinder inlet ports that will provide the cylinder with sufficient air to allow the engine to develop its rated horsepower at some particular altitude with the throttle valve open. The altitude at which the engine develops its rated—or sea-level—horsepower with the throttle wide open is known as the rated altitude. Below this altitude, it is necessary to close the throttle partially to prevent the engine from developing more than its rated horsepower. Above the rated altitude, the power commences to decrease with increase in altitude, because the supercharger cannot maintain the required pressure.

The purpose of the supercharger is not only to maintain full power at altitude by compressing the rarefied air to approximately sea-level density, but also to improve the distribution of the fuel-air mixture and to mix the fuel and air more thoroughly. It is also used to increase the sea-level power of the engine in order to provide the necessary "takeoff" and "climb" power output of the engine, by delivering compressed air instead of air of normal density.

The superchargers under discussion are of the centrifugal compressor type, and are connected by gears to the engine crankshaft. They have an internal impeller, and are best adapted to radial engines. The fuel-air mixture is compressed after the air has passed through the carburetor. In this type of supercharger, the impeller, which is a centrifu-

gal blower, receives the fuel-air mixture at the center and imparts a high velocity to it. The high, velocity mixture is discharged into carefully designed passages which lead from the impeller in a direction tangent to the direction of rotation of the impeller.

The section of the supercharger containing these passages is called the diffuser, and it is shaped so that the velocity of the mixture is decreased with the least possible friction, the decrease of velocity producing a pressure. In this manner the mixture of fuel and air is delivered to the cylinder at a pressure above that of the atmosphere, and hence in greater quantity than would be produced by suction alone, since the diffuser passages lead directly into the intake pipes of the cylinders.

The supercharger improves the distribution of the mixture by directing it to the cylinder by the most efficient path. It also improves vaporization, since the drops of gasoline that are drawn from the carburetor are exposed to a stream of air moving at high velocity. In addition, the temperature of the mixture is increased somewhat by compression, and it is well known that gasoline vaporizes much more readily as the temperature is increased.

One of the functions of the supercharger is to maintain the rated sea-level power at altitude, as stated before. Therefore, it is obvious that using it at sea level will appreciably increase the power of the engine at this level. Engines intended for high-altitude operation are not ordinarily given full throttle at sea level. The throttle on such engines is designed with a "stop" set for safe opening at sea level. If the full power of the engine is used under these conditions, undue wear or damage to the engine is likely to result. However, in emergencies, such as take-off in limited areas, the throttle lever can be moved past the stop by releasing a catch spring, usually operated by a button in the throttle handle.

A type of supercharger used on Navy airplane radial engines is shown in figure 77. Observe that the edges of the impeller blades are "bent" near the center so that they strike the fuel mixture without shock, thus reducing the power re-

quired to operate the impeller as well as increasing its efficiency. A great deal of experimental research was done to determine the exact angle at which the blades must be curved, as well as other features built into the superchargers. The impeller passage—which is the space enclosed by two of the blades and the rear face—is curved so as to bend the stream of mixture as gently as possible and lead it to the outer edges of the blade, which always lie along a radial line. The outer edges are referred to as the impeller exit.

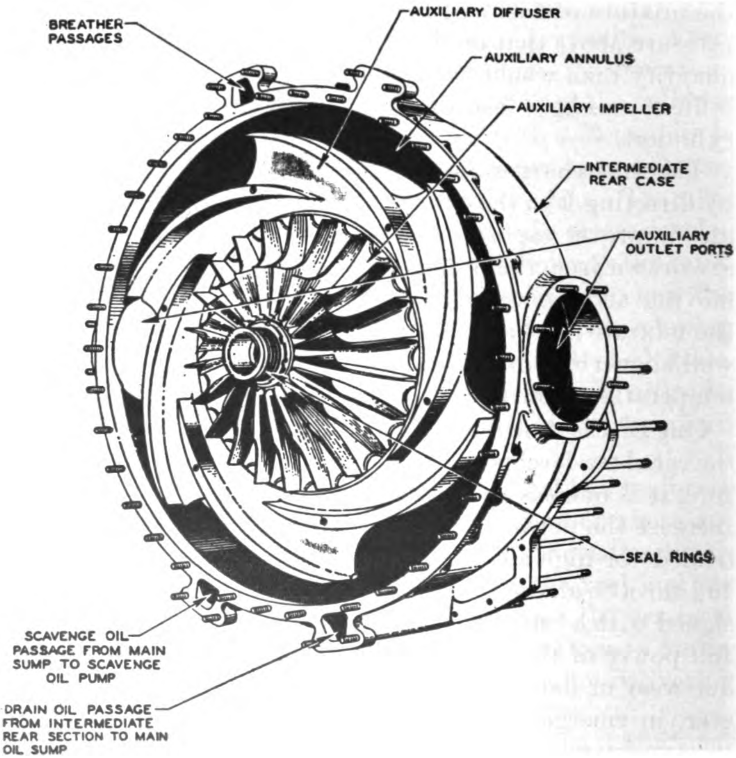


Figure 77.—Supercharger impeller and diffuser.

The impeller rotates at a high speed. The ratio between it and the crankshaft ranges from 7 to 1 to 12 to 1. Thus, if the engine is running at 2,000 r. p. m., the impeller is running from 14,000 to 24,000 r. p. m. The speed at the

outer tip of the blade—usually referred to as the peripheral speed—is from 500 to 1,500 feet per second. When you recall that sound travels slightly less than 1,100 feet per second, and that the velocity of bullets from a .45 caliber pistol is less than 1,000 feet per second, you will realize that a supercharger impeller rotates rapidly. From these comparisons, you will readily understand that the gearing and the impeller must be designed with precision. Do not forget that opening the throttle of an engine suddenly imposes severe loads on the whole supercharger mechanism. For example, if the speed of the engine is increased from 1,000 to 2,000 r. p. m., the impeller speed may be increased from 12,000 to 24,000 r. p. m. during the same period of time. In other words, while the engine speed increases 1,000 r. p. m., the impeller must increase 12,000 r. p. m. In order to prevent abuse to the impeller and its driving gears, it is customary to have a friction clutch between the impeller gear and the impeller. When sudden strains are imposed on the mechanism, the clutch slips until the impeller reaches the proper speed.

You have learned that a supercharger geared for high altitude is more effective than necessary at low altitude. Likewise, when the speed of rotation of the impeller is reduced, the same supercharger is sufficiently effective at lower altitudes. Taking advantage of these facts, many airplane engines are equipped with impellers geared so that they may be driven at two or more speeds with relation to the crankshaft. A clutch operated by engine oil pressure and controlled by a valve on the rear section controls the chain of gears driving the impeller. Each chain of gears drives the impeller at a different ratio.

The advantage of the two-speed supercharger is obvious. The low speed permits sufficient supercharging to allow the engine to develop its normal rated horsepower for takeoff and low-altitude work. At the same time the impeller speed is lessened, thereby decreasing the power necessary to turn the impeller, and also reducing the strains on the moving parts which are a natural result of continued high speed.

The two-speed supercharger is controlled from the cockpit and is shifted from low speed to high speed somewhere between 10,000 and 15,000 feet altitude, or when increased supercharging is needed.

In changing from one supercharger speed to another, partly throttle down the engine to avoid rough engagement of the clutches. Normally, such changes should not be made at intervals of less than 5 minutes, in order to give the heat generated during clutch engagements time to dissipate. In shifting gears, never hesitate in the neutral position as this causes dragging or slipping of the clutches and rough engine operation during the shifting period.

Since a drop in manifold pressure will usually accompany the supercharger shift from high to low, you should watch the manifold-pressure gage for this indication when a shift is made. To prevent "taking-off" accidentally in the high blower position, check on the drop in pressure as it is a positive indication that the control system is functioning properly. As soon as you have made the check for change in manifold pressure, reduce the engine speed to 1,000 r. p. m. or less.

If the shift does not appear to be satisfactory, continue to operate the engine at 1,000 r. p. m. or less for 2 minutes to permit the heat generated in the clutches during the shift to dissipate and then repeat the shifting procedure. Any prolonged fluctuation or loss of manifold pressure when shifting from low to high indicates improper high clutch engagement. You should, in such a case, return the blower ratio selector control to the low position and repeat the shift as just described.

Make sure that the clutch control of the supercharger is at the extreme end of its travel at all times, in order that the rated power will always be available. If the control is placed in the neutral position, the rated horsepower will not be available, and might cause a serious accident at takeoff.

When operating for extended periods in either blower ratio, it is recommended that the clutches be shifted once every 2 hours. It is necessary to remain in the opposite

blower position for only 5 minutes. Always make sure that the supercharger gears are in the low position when the engine is stopped.

TWO-STAGE SUPERCHARGERS

The principal difference between single-stage supercharging and two-stage supercharging is that the latter has two blower units—main and auxiliary—together with their driving mechanisms. The auxiliary blower, which actually is the type shown in figure 77, serves to increase the pressure of the air entering the carburetor at high altitudes, thereby increasing the altitude performance of the engine as compared with an engine having only one stage of supercharging.

The second-stage supercharger may be exhaust-driven, or driven by gearing from the crankshaft. The gear-driven auxiliary blower has two ratios to the crankshaft, and the main blower has only one. The exhaust—or turbo—type of supercharger may be used not only to assist in engine operation, but also to compress the air that is led into the cabin, and thus reduce the necessity of oxygen tanks and masks being used by the occupants of the airplane.

In figure 78, you will see a diagram showing a typical turbo supercharger. The airplane engine in the illustration is purely diagrammatic, as are also the turbine, the air-cooler, and the carburetor. The air-cooler is located at the right-hand side of the turbine, a passage leading from it to the engine. A second passage connects the carburetor with the intake valve of the engine cylinder—which is the valve shown closed in the illustration—and the large passage at the top conducts the exhaust gases from the exhaust valve to the nozzle box of the turbine.

From the nozzle box, the exhaust gases are directed through a nozzle diaphragm against the turbine buckets. On the turbine shaft is mounted an impeller, or centrifugal blower, which acts as an air compressor, the compressed air being led through the cooler and thence to the carburetor intake. The turbo supercharger is lubricated through its own oil system, which is ordinarily connected to the engine supply.

The operation of the supercharger is as follows. The flow of exhaust gas from the exhaust valve of the engine through the large upper passage to the nozzle box of the turbine is regulated by a blast gate, or waste gate. The operation is similar to that used in the gear-driven blower. The gate is provided to allow the exhaust gases to escape to the atmosphere without operating the turbine when the airplane is flying at low altitude. The blast gate is generally operated automatically, but may also be operated by hand in most installations.

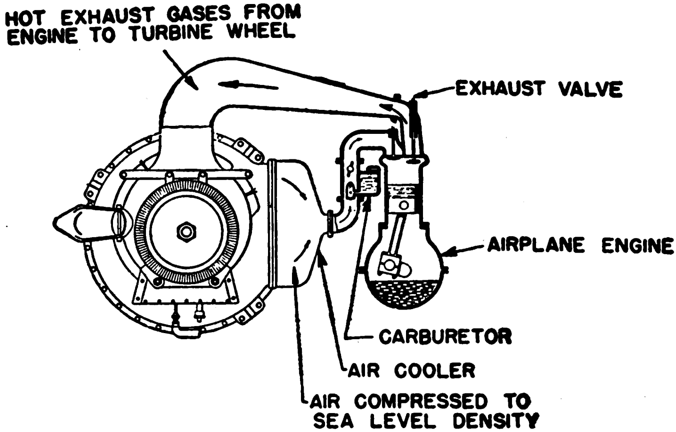


Figure 78.—Turbo supercharger.

As the density of the air begins to decrease causing a gradual drop in the engine power, the blast gate begins to close, directing more and more exhaust gas into the nozzle box and thence against the turbine. The speed of the turbine increases, and, since the impeller of the supercharger is mounted on the turbine shaft, the impeller speed also increases, producing more and more air pressure.

A state of equilibrium, or balance, is finally reached in which the back pressure of the engine is held at about 28 inches of mercury, and the pressure at the intake of the carburetor is held at the same value. The gradual closing of the blast gate helps to keep this balance until the critical

altitude is reached, 25,000 feet or more, at which point the engine power gradually diminishes.

The opening and closing of the blast gate is accomplished either by the automatic control, operated by oil from the engine lubrication system, or by manual operation from the cockpit. The speed of the turbine, and hence the impeller speed, increases approximately 1,000 r. p. m. for each thousand feet of altitude. Thus at 25,000 feet, the turbine and the propeller are turning about 25,000 r. p. m. Since this compression of air produces a heat of about 300° F., and since the temperature should be kept near 175° F. for satisfactory operation, an air cooler must be installed between the impeller and the carburetor as shown in figure 78.

The external exhaust-driven supercharger must be located so that its turbine will receive the exhaust gas with the least flow loss in the piping, and also so that the flow loss in the induction system is at a minimum. The carburetor is usually located between the blower and the cylinder inlet ports, as you will see in the illustration. In such an installation, it is necessary to provide some metering control in the carburetor to take care of the changing air density, since a carburetor normally meters fuel in proportion to the volume of air metered through it and without regard to the mass (weight) of air metered.

The gear-driven two-stage supercharger is shown in a schematic diagram in figure 79. The air enters the outside air intake located in the engine cowling, in the leading edge of the airplane wing, or at some other convenient point, and flows through the automatically operated gate valve into the auxiliary, or secondary, blower. The air compressed by the auxiliary impeller passes through an intercooler which reduces the high temperature resulting from compression, and then enters the carburetor. From this point, the induction system is essentially the same as that of a single-stage supercharger. Passing through the carburetor the air mixes with the fuel and enters the main stage blower.

The auxiliary supercharger regulator is adjusted to maintain a pressure of about 28 inches of mercury at the outlet

of the auxiliary blower by controlling the position of the auxiliary-stage gate valve—as in the case of the exhaust-driven blower. The various ducts and intercoolers cause a pressure drop which may run as high as 2 inches of mercury resulting in a carburetor pressure of about 26 inches. At relatively low powers, and the corresponding airflows, the pressure drop will be less than 2 inches, and the pressure at the carburetor will be almost equal to that at the auxiliary blower outlet.

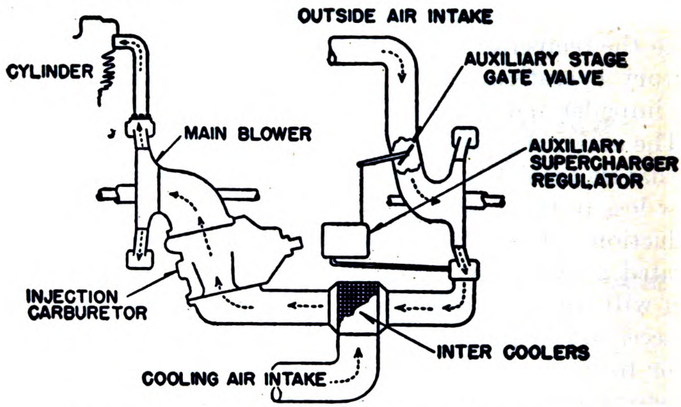


Figure 79.—Schematic view of supercharger two-stage control.

The engine operates in any one of the blower ratios—neutral, low, or high—essentially as a single-speed, single-stage engine. The best performance will be obtained by remaining in one blower ratio at full throttle until the manifold pressure is 3 or 4 inches lower than the value that will give the desired power. At this point you should shift to the next higher blower ratio—neutral to low, or low to high—by moving the control lever without hesitation to the new position. During "climbs" at high power and high r. p. m. do not close the throttle partially before the shift, but, at the lower powers and r. p. m. close the throttle partly to reduce the manifold pressure another 3 or 4 inches. At the higher powers, the auxiliary supercharger regulator will limit manifold pressure to the maximum permissible values. At lower powers, it will be necessary to use the manual throttle to pre-

vent excessive manifold pressures. Two or three trials will be sufficient to acquaint you with the throttle movement necessary to prevent excessive manifold pressure when the shift has been made.

At high altitudes in the low blower ratio, and at still higher altitudes in the high ratio, manifold pressure at full throttle will not exceed the maximum values for the desired power conditions. You should regulate the power with the propeller control. In general, operate in the lowest blower ratio that will provide the desired power.

Under some circumstances when the auxiliary blower is shifted from neutral to low, or from low to high, the carburetor may not respond rapidly enough for the sudden change in air pressure at the carburetor. Consequently, the strength of the mixture may be temporarily too lean causing the engine to cut out momentarily. Such a condition can usually be avoided by shifting from neutral to low below 10,000 feet, and from low to high below 20,000 feet.

You may have a "surging" condition of the engine while operating with the auxiliary blower engaged if the hand throttle is partially closed. This surging results from an unstable condition of air flow through the engine induction system which may result in severe periodic variations in r. p. m. power, and manifold pressure. To return the engine to normal operation, open the hand throttle or shift the auxiliary supercharger control to a lower position. If conditions are such that full power is required after a short period at lower power, you can "ease up" the surging by reducing the engine speed with the propeller control.

The extent to which surging will occur depends somewhat on the design of the induction system of the airplane. Consequently, it may be "wise" to determine from flight tests the lowest manifold pressures to which the engine may be throttled while operating at high r. p. m. with the auxiliary supercharger engaged.

In general, surging may be eliminated completely by operating at or near full throttle, and using the propeller control to regulate the power. Remember that this practice is

good only at altitudes sufficiently high to keep manifold pressure from becoming excessive.

The maximum safe carburetor air temperature for all operation with the auxiliary supercharger engaged is 90° **F.** or 32° C. If the intercoolers have controllable shutters, leave them fully open during all normal operations unless the airplane performance is affected adversely, or carburetor icing conditions make necessary a higher air temperature to the carburetor.

In installations in which the flow of cooling air through the intercooler is controlled by adjustable accessory compartment flaps, the closed position must be designed to provide adequate cooling for high-power level flight operation. During "climbs" in which the auxiliary supercharger is used, these flaps must be at least partially open.

QUIZ

1. (a) What is the primary function of the supercharger?
   (b) What are some of its other valuable functions?
2. (a) Why should the supercharger not be used at sea level except in emergencies?
   (b) How can you be sure the supercharger is not in the high-blower position at takeoff?
3. (a) How does the speed of the supercharger compare with the speed of the engine?
   (b) What limitation is placed on throttle-operation because of this?
4. What is the function of the blast gate in a turbo supercharger?
5. Rated altitude is the altitude at which the engine develops its rated horsepower with the throttle ____________________.
6. The impeller passage is the space between two of the blades and the ____________________ face.
7. The gearing and the impeller of a supercharger must be designed with ____________________.

8. The two-speed supercharger is controlled from ________________.

9. Any prolonged fluctuation or loss of manifold pressure when shifting from low to high indicates improper ________________.

10. The auxiliary supercharger regulator is adjusted to maintain a pressure of about __________ inches of mercury.

    a. 28.
    b. 30.
    c. 26.
    d. 15.

11. In general, surging may be eliminated completely by operating at or near ________________.

CHAPTER 11

INTRODUCTION TO TURBO-JET FUEL SYSTEMS

Heat energy added to the airflow taken in from the surrounding atmosphere by turbo-jet engines causes the exhaust velocity to exceed the intake velocity. This increase in the velocity produces the thrust required to fly the aircraft. The present method for adding this heat energy to the airstream is by the combustion of atomized hydrocarbon fuels in the airstream.

The processes that occur in the combustion chamber are the atomization of the liquid fuel by the injection nozzle, the vaporization of the liquid droplets by the heat radiated and conducted to them, the preignition reactions between the hydrocarbon and the oxygen in the air, the ignition and combustion of the mixture, and finally the mixing of the hot combustion product with excess air.

Turbo-jet fuel systems usually consist of a filter, an engine-driven pump, a throttle valve, and an engine-driven overspeed governor. Some systems also have a starting pump used in parallel with the engine-driven pump.

Operating only when the starter is actuated, the starting pump provides sufficient fuel and fuel pressure for starting at low engine speeds. The throttle valve is the only means of fuel control. Limiting the fuel flow and the maximum r. p. m. of the turbine, the overspeed governor is an automatic device which overrides the manual throttle fuel valve.

Some turbo-jet engines have a controllable area tail nozzle to change the area ratio between the turbine outlet and the tail nozzle. The purpose of this is to vary the turbine outlet pressure at a given altitude.

In the early stages of the development of jet turbines, it was believed that turbines could be operated on almost any liquid fuel. However, efforts to achieve higher efficiency and better performance have already emphasized certain fuel properties which make the gas turbine quite discriminating in its taste for fuels.

The most satisfactory fuel is the one which is most economical in cost, upkeep and supply. Since a wide range of fuels is available, differing in physical and chemical properties, combustion characteristics, and costs, we need to study the requirements of the aircraft engine and the needs of the pilot in the light of available fuels.

Various types of fuels can be used in the turbo-jet engines. While kerosene and all of our present aviation fuels can be used without appreciable difference in performance, some fuels reduce internal wear better than others making longer life for the moving parts. Other fuels coat the vanes in the combustion chamber with lead and necessitate more overhaul costs and losses.

With these things in mind, the necessity of special fuels for the jet engines is clear. As can be seen in the following paragraph AN–F–58 has been developed. When necessary other fuels can be substituted for this fuel, however, be sure to use the lowest grade of aviation gas when it becomes necessary. This will reduce the amount of lead deposited upon the nozzelguide vane, turbine blades, and turbine shroud rings.

Recent tests with the Turbo Wasp engine illustrate the lower cost of operation with a nonleaded fuel. After operating for 150 hours under specified conditions for the model test, the engine was disassembled, inspected, and the lead removed from the working parts. The engine was then reassembled and tested for its performance. These tests indicated that at takeoff r. p. m. the thrust had decreased approximately 9 percent; at takeoff conditions, fuel consumption had increased 5 percent; and at low cruise, specific fuel consumption had increased a little over 3 percent.

After the lead deposits had been removed the engine returned to normal operation. The conclusions drawn are obvious.

The following aircraft engine fuels have been authorized for use in Naval aircraft and are available as noted below:

Grade	*AN Specification*	*Type*	*Color*	*Remarks*
80	AN–F–48	Aviation gasoline	Red	Note (1).
91/98	AN–F–48	Aviation gasoline	Blue	
100/130	AN–F–48	Aviation gasoline	Green	Note (2).
115/145	AN–F–48	Aviation gasoline	Purple	
JP–1	AN–F–32	Aviation kerosene	Clear	Note (3).
JP–3	AN–F–58	Gas turbine fuel	Clear	Note (4).

Note (1).—Replaces Grade 73, may have a maximum of 0.50 ml of tetraethyl lead per U. S. gallon.

Note (2).—Will be used only as a substitute for Grade 115/145 whenever Grade 115/145 is not available in sufficient quantities.

Note (3).—Will be used in gas turbine engines designed to use aviation kerosene. This fuel will eventually be replaced by AN–F–58 and/or AN–F–48 as the engines are modified to use gasoline type fuels.

Note (4).—This fuel will replace AN–F–32 for use in all gas turbine engines. All four grades of Specification AN–F–48 aviation gasoline are designated as alternate fuels for gas turbine engines designed for Specification AN–F–58 fuel. Whenever AN–F–58 fuel is not available, the lowest grade of aviation gasoline that is available may be used.

FUEL TANK ARRANGEMENTS

Turbo-jet aircraft have this factor in common with conventional type airplanes: they need storage space for their fuel, regardless of the type of fuel. Also, as in conventional airplanes, these tanks are divided into auxiliary and main tanks.

Auxiliary tanks may be inside the fuselage, inside the wings, or mounted externally in such a manner as to be dropped when necessary. This external mounting may be on the ends of the wings, on the wings between the tips and the fuselage, or on the belly of the aircraft.

With wings extended, external fuel tanks are filled in the conventional manner making certain that the hose connection is grounded. Many units facilitate filling their external wingtip tanks when the wings are folded by using a ladder. The ladder fastens to the wing and the plane captain is able to reach the tank with the hose.

The fuel in all tanks normally passes through the main tank before passing into the system. The auxiliary tank to

be used is selected by the pilot or the aviation machinist's mate by means of the tank selector valve. Fuel travels through the tank selector valve, through the fuel transfer pump, and through the standby selector valve. Under normal operating conditions the fuel must travel from the standby selector valve into the main tank.

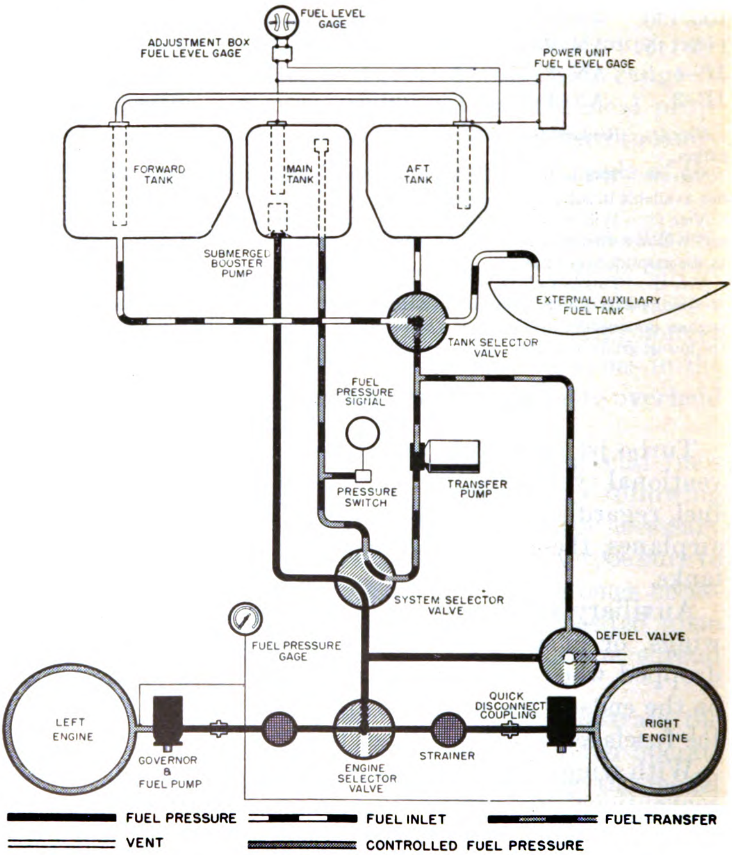


Figure 80.—Fuel system diagram of the Phantom.

Usually there is a float valve in the main tank to control the transfer of fuel into the main tank. The fuel system of the Phantom, FH-1, shown in figure 80, illustrates this system

with its main tank, an after tank, a forward tank, and the external auxiliary fuel tank. Although the after and forward tanks of the Phantom are actually main fuel tanks, we will consider them auxiliary tanks.

When an emergency arises, and for some reason it is impossible to transfer fuel from the auxiliary tanks to the main tank, it is not necessary to call "Grampaw Pettibone." The system selector valve is placed in the "STANDBY" position cutting off the fuel from the center tank. This permits the direct withdrawal of fuel from the auxiliary tank selected without the possibility of it being forced back into an empty tank. It makes no difference whether the transfer pump is operating. This arrangement enables all of the fuel in the fore and aft tanks to be used in the event of complete electrical failure.

FUEL SYSTEMS

Since fuel systems are somewhat similar from one jet aircraft to another, that of the Phantom will be described in the next few pages of this book.

FH–1 Phantom

Referring to figure 80, we see that there are three fuselage fuel tanks of the self-sealing type in the Phantom. These tanks are located in the upper section of the fuselage, aft of the pilot. A fuel strainer is located in the bottom of each tank, the strainer in the center tank forming an integral part of the submerged booster pump. Fittings on the bottoms of the tanks are provided to connect the fuel lines and drain lines. A float valve is installed in the center tank only.

The tank selector valve of the Phantom is a balanced type four port selector valve. Self-sealing lines from the front and aft tanks and the line from the droppable tank are connected to the side ports of the valve. The fuel outlet line is at the bottom port. The tank selector valve is in the system to control the flow of fuel from the droppable, aft, and forward tanks. The tank selector valve does not control the fuel drawn from the center tank (main tank) as it is connected directly into the system. It is well to remember that

no repairs should be made or attempted on the tank selector valve. A worn or damaged selector valve should be replaced.

Allowing the fuel to flow from the transfer pump to the main tank, and the fuel from the submerged booster pump to flow on to the engine selector valve, is the job of the SYSTEM SELECTOR VALVE. This takes place in the NORMAL position of the switch. Should there be a failure of the booster pump or should there be the necessity for defueling, the switch is placed in the STANDBY position and the fuel from the transfer pump flows directly to the engine selector valve, and bypasses the main tank.

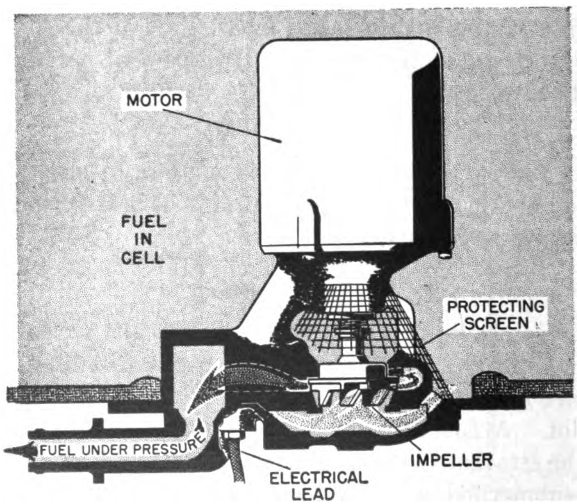


Figure 81.—Submerged booster pump.

The system selector valve is a four port, two position selector valve. Connected to one port is a line from the fuel transfer pump carrying the fuel from the front, aft, and droppable tanks. Connected to another port is a line which carries the fuel to the main tank. This is the line into which the fuel pressure signal switch is connected. Another line connected to the system selector valve is from the submerged booster pump in the main tank. The valve is controlled by a mechanical linkage to the control handle in the cockpit.

The submerged booster pump, figure 81, is essentially an integral unit composed of a centrifugal pump and an electric motor. A screen is provided to strain the fuel and to protect the pump from foreign matter.

The submerged booster pump delivers fuel to the system under a set pressure. Only one pump is needed in the system since all fuel normally passes through the main tank for use by the engines of the aircraft.

TROUBLE SHOOTING SUBMERGED BOOSTER PUMP

Trouble	*Probable cause*	*Remedy*
Pump refuses to rotate.	Foreign matter between rotor assembly and liner.	Replace pump.
	Pump run dry and allowed to jam.	Replace pump.
	Spline drive shaft sheared due to foreign matter jamming pump.	Replace pump.
Discharge pressure too low.	Loose or high resistance in the electrical connections.	Clean and tighten.
	Low voltage	Check voltage at motor connection.
	Gasoline in motor	Examine by removing the ⅛-inch pipe plug in the commutator end frame.
	Rough or pitted commutator.	Replace pump.
	Shorted, grounded or open motor field coils.	Replace pump.
Excessive current demand.	Incorrect voltage	Check and correct.
	Damaged or worn bearings.	Replace pump.
	Bent shaft or commutator out of round.	Replace pump.
Motor noisy	Worn or brinelled bearings.	Replace pump.
	Parts not properly tightened in assembly.	Check and tighten properly.

FUEL TRANSFER PUMP

The fuel transfer pumps are installed in the system to pump the fuel contained in the various auxiliary tanks to the main tank. They usually consist of a rotary valve pump and an electric motor with a gear reduction.

TROUBLE SHOOTING FUEL TRANSFER PUMP

Trouble	*Probable cause*	*Remedy*
Pump noisy	Loose mounting	Tighten mounting bolts and hose line connection, if found to be loose.
	Bearing worn	Replace pump.
Pump fails to operate.	Wiring not properly connected.	Remove from connector and clean connecting lead thoroughly. Replace making sure connection is tight. Check to make sure wiring is properly hooked up.
	Loose or high resistance in connections.	Clean and tighten.
	For any other reasons	Replace pump.
Unsteady or erratic pressure.	Loose connections	Check and tighten.
	Voltage variation	Check to make certain voltage applied to pump is correct, and make sure wiring is properly connected.
	Pump screen clogged	Remove, clean and return to service.
Pressure too low	Loose connections	Check to tighten.
	Worn brushes in motor	Replace pump.
	Gasoline in motor (indicates possible bearing failure).	Replace pump.

FUEL FLOW CONTROL

One thing to remember in jet engine systems is that the familiar carburetor of the reciprocating engine is no longer

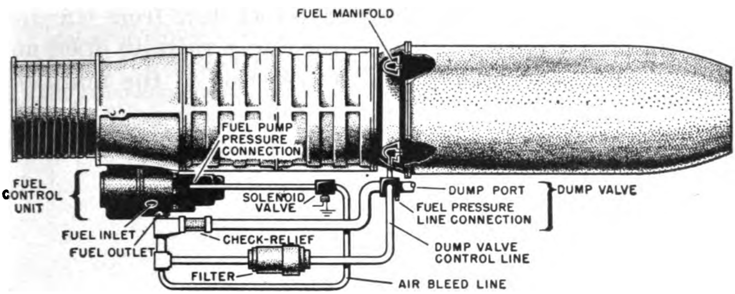


Figure 82.—Jet fuel system schematic.

present. In the reciprocating engine, the carburetor meters the fuel necessary for combustion with the air. In the jet engine it is practically impossible to control the flow of air coming into the jet system. One type of fuel control used in jet fuel systems is the barometric or constant displacement system. The fuel control unit or governor used in jet systems will be discussed basically.

Referring to figure 80, there is a separate governor (fuel control unit) that incorporates a fuel pump in the fuel line which delivers the fuel to each engine.

In operation, filtered fuel under booster pressure enters the positive displacement fuel pump section of the fuel control. The fuel is discharged from the fuel control at a high pressure and is carried rearward through an external tube to the fuel dump valve. An internal tube connects the dump valve to the fuel manifold to which the fuel nozzles are attached. The fuel is sprayed from the nozzles, figure 83, and mixes with the compressed air and is burned in the liner.

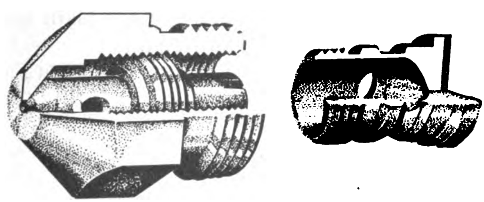


Figure 83.—Fuel nozzle cutaway.

When the engine is shut down, the fuel flow from the fuel control is shut off which allows the dump valve to open and drains all the residual fuel that remains in the manifold providing a clean cutoff of combustion.

QUIZ

1. Heat energy added to the airflow taken in from the surrounding atmosphere by turbo-jet engines causes ____________ to exceed intake velocity.
2. Controllable area tail nozzles are used to change the ____________ between the turbine outlet and the tail nozzle.
3. The principal reason aviation gases are detrimental to turbo-jet engines is because ___________.
4. ___________ is the gas turbine fuel used at the present time.
   a. AN–F–48.
   b. AN–F–32.
   c. AN–F–58.
   d. Grade 80.
5. When using aviation gasoline in a turbo-jet, use the __________ grade possible.
   a. highest.
   b. lowest.
   c. any.
   d. none of the above.
6. Under normal operating conditions, fuel must travel from the standby selector valve ___________.
   a. into the engine.
   b. into the main tank.
   c. into the forward auxiliary tank.
   d. to the submerged booster pump.
7. Usually there is a ___________ valve in the main tank to control the transfer of fuel into the main tank.
8. In the Phantom, the order for withdrawing fuel is ___________.
   a. droppable, forward, aft.
   b. aft, forward, droppable.
   c. forward, droppable, aft.
   d. droppable, aft, forward.
9. The starting pump of a turbo-jet fuel system operates only when ___________.

10. The tank selector valve of the Phantom is a __________ four-part selector valve.
11. A worn or damaged selector valve should __________.
12. The submerged booster pump is essentially a __________ pump and an electric motor.
13. Through what tank does all the fuel used pass?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

KINDS OF FUEL SYSTEMS

1. When it is mixed with the proper proportion of air or oxygen.
2. Because the burning is not instantaneous, but starts at the point of ignition and spreads progressively through the charge.
3. To measure the actual pressure of the fuel entering the carburetor.
4. Relief valve.
5. Vaporize.
6. Pumping.
7. Relief valve.
8. Supercharger.

CHAPTER 2

TANKS AND TUBING

1. Be sure workroom is properly ventilated.
   Circulate air through tank if possible.
   Wear an organic-vapor respirator for work inside the tank.
2. 3 inches. 1 inch.
3. (a) Bonding.
   (b) To prevent electrical interference with radio reception.
4. A mixture of 25 percent lead soap and 75 percent mineral oil.
5. Reserve—so that some gasoline will be used from the main tank first to insure space for the fuel that will be returned from the carburetor by the vapor-return system.
6. (a) To lessen the danger of fire or explosion, in the tanks, under gunfire.
   (b) By providing a noninflammable atmosphere within the tank and keeping the pressure in the tank within the limits for which the tank was designed.
7. To avoid the possibility of attempted take-off on an empty, or almost empty, tank.
   To avoid an undesirable effect on the airplane's center of gravity.
8. Self-sealing fuel cells.
9. Aluminum alloy.
10. Several plies of cord and rubber.
11. Dichromate crystals.
12. Three.
13. Aluminum alloy.
14. Centrifugal.

15. Ground.
16. Daily.

CHAPTER 3

FUEL-LINE ACCESSORIES

1. Atmospheric and engine temperatures.
2. Intake.
   Carburetor.
   Supercharger.
3. Dirt in check valves.
   Loose or worn-out plunger packing.
4. Because a column of fuel in the gage line will exert a downward pressure which cancels a portion of the pressure at the carburetor.
5. (a) Test the gage against a standard gage of known accuracy.
   (b) Compare the manifold-pressure reading with the altimeter barometric pressure reading when the engine is not running.
6. It should "click" audibly when the lever is moved to the new position.
7. Gasoline spray.
8. Open to air pressure in the cockpit.
9. Manifold pressure gage.
10. Not to exceed the proper carburetor pressure.

CHAPTER 4

FUEL PUMPS

1. Bypass valve.
2. To maintain constant pressure at the carburetor by returning fuel to the inlet side of the pump or to the fuel-storage tank whenever the pressure becomes excessive.
3. Dirt or some obstruction in the valve assembly, or in the air vent line and vented pipe plug at the supercharger air connection.
4. (a) Leaks, cracks, or worn spots, in tubing.
   Security of clips and other mountings.
   (b) Cracks, buckling, dents, distortion or signs of leaks, in tanks.
   Security of tank mounting supports.
   Padding.
5. A relief valve.
6. Directly on the engine.
7. Relief.
8. Notify your superior officer.
9. Continuous, proper pressure.
10. Into the fuel pump.

11. Discharge.
12. Is not dependent.
13. The main engine driven pump.

CHAPTER 5

CARBURETION

1. (a) To meter the incoming fuel and air in the proper proportions. To vaporize as much of the fuel as possible.
   (b) Vaporizing fuel draws heat from the surrounding air, and the vaporization of a volatile fuel may thus lower the temperature of incoming air to a point where moisture in the air will condense and freeze.
2. (a) Vapor lock.
   (b) Because the presence of vapor in any part of the line may block the flow of the liquid fuel needed by the engine.
   (c) Because the boiling point is lower at higher altitudes.
3. (a) Antiknock characteristic.
   (b) It makes it possible to use a higher compression ratio in the engine cylinder without fuel detonation, thus utilizing more power per pound of gasoline and increasing the power-weight ratio of the engine.
   (c) Because the chief advantage of the antiknock fuel is not effective unless the engine is mechanically adjusted to exploit it through higher compression ratio.
4. (a) A mixture in which the ratio of gasoline to air is relatively high.
   (b) Because a given volume of air drawn in at high altitude will weigh less than an equal volume drawn in at a lower altitude.
   (c) Mixture control.
5. (a) Lean. Because the idling jet stops functioning immediately and there is a lag in the fuel stream until enough air flows through the carburetor to start the main metering jet functioning.
   (b) Accelerator system.
6. Gum.
7. 100.
8. Only in engines.
9. Idling passage.
10. The priming system.
11. 15 to 1.
12. Detonations.
13. Octane.
14. Analine dye.

15. Auxiliary.
16. Richer.

CHAPTER 6

FLOAT-TYPE CARBURETOR

1. (a) Throttle valve.
   (b) No. A fuel discharge orifice located at the edge of the throttle valve supplies fuel from the "idle" system when throttle is closed.
2. The idle system.
3. (a) Updraft carburetors draw in air at the lower part of the carburetor, while the downdraft type has its air inlet at the top.
   (b) Downdraft.
4. With the mixture-control in this position, the suction transmitted from above the closed throttle valve to the top of the float chamber stops all flow of fuel from that chamber. Lacking fuel, the engine will stop running.
5. (a) To direct the fuel jet into the air stream.
   (b) The throat of the venturi.
   (c) It is lower than atmospheric pressure.
   (d) It makes the gasoline vaporize more readily. Because the boiling point is lower at reduced pressures.
6. In a horizontal line extending laterally through the center of the float chamber, in order to maintain the fuel level throughout various airplane attitudes.
7. The fuel flows from the interior vertical fuel passage into the air stream through radial holes drilled in the surface of the nozzle. This change in flow direction immediately before delivery to the air stream is claimed to assist in the mixing.
8. Air-bleed.
9. Mixture control.
10. Service and absolute.
11. Airflow through the venturi.
12. More rapid vaporization.
13. Butterfly.
14. By the twist drill and wire-gage standard.
15. Fuel leakage.

CHAPTER 7

STROMBERG FLOAT-TYPE CARBURETORS

1. The NA–R9C2 throttle-lever requires slightly more movement ($2\frac{19}{64}''$ as compared with $2\frac{18}{64}''$ on the NA–R9B).

2. (a) NA–R9C2. Needle-valve.
   (b) Both. NA–R9C2.
   (c) NA–R9B. Needle-type (manual). NA–R9C2. Back-suction type (Manual and automatic).
3. (a) It indicates that the engine is overprimed.
   (b) No. Heavier fractions of the gasoline do not vaporize at low temperatures, and may collect in and drain from the supercharger.
4. (a) 3/8''.
   (b) 1/32''.
5. Assemble plates and gaskets to both carburetor flanges and apply air pressure of 3 to 5 p. s. i. to the inside of the carburetor through a connection made in one of the plates. Immerse the carburetor and watch for air bubbles.
6. Sealed bellows.
7. To show the correct position of the mixture-control lever for stopping the engine.
8. (a) Graphite and castor oil.
   (b) Shellac.
9. Main jet plug.
10. Excess fuel.
11. Idling speed, mixture.
12. 30-hour check.
13. The engine is given a complete overhaul.
14. Compressed air.
15. 6.

CHAPTER 8

STROMBERG INJECTION CARBURETOR

1. (a) NA–Y 9 C

C — Major design change.

9 — Rated size.

Y — Double-barrel, with Y-type double-float mechanism, double-float chamber, and single needle valve.

NA — Natural atomization (float type).

PT-13 E 2

- 2 — Minor design modification.
- E — Major design change.
- 13 — Rated size.
- T — Triple-barrel.
- P — Injection type.

(b) $9 = 3\frac{3}{16}''$ barrel.
$13 = 4\frac{3}{16}''$ barrel.

2. Throttle body.
   Mixture-control unit.
   Regulator unit.
   Fuel-control unit.
   (Adapter).
3. (a) It exerts so much pressure on the valves that they tend to "creep" shut.
   (b) Throttle balance.
4. By lowering the temperature of the fuel charge in the intake manifold so that a lean mixture (the best power-mixture strength) can be used without detonation.
   By making it possible to increase the pressure in the intake manifold.
5. No. The various other units in the fuel system will operate normally, as though the system had been purposely inactivated.
6. Because stiff new diaphragms will soften up after soaking in gasoline.
   The idle setting must then be readjusted to the flexible diaphragms.
7. To prevent vapor-lock.
8. Make sure that the vent channels between the throttle body and the engine are not obstructed.
   Make sure that the outside fuel tube is connected properly, and that its joints are tight.
9. They must be capable of idling at 600 r. p. m. with exhaust stacks, or at 450 r. p. m. with exhaust collectors.

10. Size and air capacity.
11. Double-barrel.
12. No fuel is discharged into the venturi.
13. Counterclockwise.
14. To the rear.
15. After the engine has been brought up to emergency power.
16. Any position.
17. 800.

CHAPTER 9

TESTING AND MAINTENANCE OF CARBURETORS

1. (a) Suction is applied to the pressure-regulator unit at a value corresponding to the airflow for each engine operating condition. The resulting fuel flow from the metering jets is measured and checked against the carburetor-setting specification sheets and other standard data.
   (b) None.
2. (a) To prevent the accumulation of gasoline vapor.
   (b) The floor. Because gasoline vapor is heavier than air.
3. Check the specifications and setting to see that the carburetor is the correct one for the engine on which it is installed.
4. Flight test.
5. F/A.
6. Fire extinguishing equipment.
7. Gasket compound.
8. Acorn nut.
9. Improper carburetion.
10. Flow bench.
11. Cannot be used.
12. Explosion.
13. 2.
14. Blank mixture-control bleed.
15. Specifications and settings.

CHAPTER 10

AIRCRAFT-ENGINE INDUCTION SYSTEM

1. (a) To offset the decreased density of air at high altitudes by compressing the air before it reaches the engine cylinders.
   (b) Increase the sea-level power of the engine, mixes the fuel and air more thoroughly (by improving vaporization) and improves the distribution of the fuel-air mixture.

2. (a) Engine power would be increased more than necessary, and the engine might be damaged.
   (b) The position of the supercharger will be indicated by the pressure registered on the manifold-pressure gage.
3. (a) The supercharger impeller rotates at a speed from 7 to 12 times as great as that of the engine crankshaft.
   (b) The throttle should not be opened suddenly.
4. To allow the exhaust gases to escape to the atmosphere without operating the turbine when the airplane is flying at low altitudes.
5. Wide open.
6. Rear.
7. Precision.
8. The cockpit.
9. High clutch engagement.
10. 28.
11. Full throttle.

CHAPTER 11

INTRODUCTION TO TURBO-JET FUEL SYSTEMS

1. Exhaust velocity.
2. Area ratio.
3. Of the lead deposits left behind.
4. C.
5. B.
6. B.
7. Float.
8. D.
9. The starter is actuated.
10. Balanced.
11. Be replaced.
12. Centrifiugal.
13. Main.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

AVIATION MACHINIST'S MATES (AD)

RATING CODE NO. 6200

General Service Rating

Scope

Aviation machinist's mates maintain, service, inspect, test, adjust, replace, preserve, and depreserve: Aircraft power plants and accessories; propellers and accessories; pumps; and oil, fuel, and water injection systems, excluding tank replacement; operate aircraft power plants and aircraft auxiliary power units for operational or test purposes.

Emergency Service Ratings

AVIATION MACHINIST'S MATES E (Engine Mechanics), Rating Code No. 6201 -- ADE

Maintain, service, replace, preserve, and depreserve aircraft power plants and attached accessories; perform operational tests of power plants.

AVIATION MACHINIST'S MATES F (Flight Engineers), Rating Code No. 6202 -- ADF

Ground service aircraft and aircraft power plants for flight; perform duties of flight engineer.

AVIATION MACHINIST'S MATES P (Propeller Mechanics), Rating Code No. 6203 -- ADP

Maintain, service, replace, inspect, test, adjust, preserve, and depreserve aircraft propellers and propeller accessories.

AVIATION MACHINIST'S MATES G (Carburetor Mechanics), Rating Code No. 6204 -- ADG

Maintain, service, replace, inspect, test, adjust, preserve, and depreserve aircraft fuel systems including carburetors and fuel metering devices.

Navy Job Classifications and Codes

For specific Navy job classifications included within this rating and the applicable job codes, see Manual of Enlisted Navy Job Classifications, NavPers 15105 (Revised), codes AD–6400 to AD–6599.

Qualifications for Advancement in Rating	*Applicable Rates*				
	AD	ADE	ADF	ADP	AD
100 PRACTICAL FACTORS					
101 OPERATIONAL					
1. Observe applicable safety precautions and emergency procedures while maintaining, servicing, and inspecting aircraft and during power plant run-up	3	3	3	3	
2. Perform daily and preflight inspection and service aircraft in accordance with current directives	3	3	3	3	
3. Start, perform run-up checks on, and shut down aircraft power plants; demonstrate ability to cope with emergencies incident to these operations	3	3	3	3	
4. Operate auxiliary power units required for aircraft operation and maintenance	3	3	3	3	
5. If assigned to activities requiring flight engineers, perform the following:					
a. Follow the proper engineering procedures for operating aircraft power plants before, during, and after flight including taxiing, take-off, climb, cruise, and landing	2	--	2	--	
b. Recognize specific signs of malfunction of aircraft power plants from observation of instruments and, when possible, make adjustments in flight	2	--	2	--	
c. Demonstrate ability to cope with power plant operational emergencies	2	--	2	--	
d. Demonstrate ability to use power charts for power plants in aircraft of activity to which attached	1	1	2	--	
6. Prepare weight and balance manifest and direct loading of aircraft, using load adjuster	1	1	2	--	

Qualifications for Advancement in Rating	AD	ADE	ADF	ADP	ADG
0 PRACTICAL FACTORS—Continued					
1 OPERATIONAL—Continued					
7. Determine weight and balance condition of aircraft on portable weighing equipment, using appropriate charts and forms	C	C	C	--	--
2 MAINTENANCE AND/OR REPAIR					
1. Demonstrate safe and proper use and maintenance of hand tools and measuring instruments required to maintain and service aircraft power plants and accessories	3	3	3	3	3
2. Read and work from aviation working diagrams, blueprints, and schematic drawings required in the maintenance of aircraft power plants and accessories	3	3	3	3	3
3. Clean, inspect, lubricate, and field-track aircraft propellers	3	3	3	3	2
4. Perform periodic checks on aircraft power plants in accordance with approved procedures	3	3	3	2	--
5. Inspect aircraft fuel systems and water injection systems. Clean and replace strainers and filters	3	3	2	--	3
6. Replace and adjust mechanical components of aircraft fuel and water injection systems including carburetors, pumps, valves, metering devices, and injectors	2	2	--	-	3
7. Disassemble, assemble, effect authorized repair, and balance aircraft propellers	2	--	--	3	--
8. Preserve and depreserve aircraft power plants and accessories in accordance with current directives	2	2	--	2	2
9. Demonstrate safe and proper use and maintenance of power-driven tools required to maintain aircraft power plants, propellers, and accessories	2	2	--	2	2

Qualifications for Advancement in Rating	Applicable Rates				
	AD	ADE	ADF	ADP	ADG
100 PRACTICAL FACTORS—Continued					
102 MAINTENANCE AND/OR REPAIR—Con.					
10. Set up, operate, and maintain carburetor flow benches. Test flow, pressure, and operation of carburetors and water injection systems	--	--	--	--	2
11. Set up, operate, and maintain testing equipment for aircraft propellers and propeller accessories	--	--	--	2	--
12. Inspect, adjust, and replace aircraft power plant accessories, including pumps, control valves, magnetos, ignition coils, distributors, starters, generators, and oil coolers	2	2	1	--	--
13. Remove, clean, inspect, adjust, install, and test-operate aircraft propellers and propeller accessories including relays, valves, and governors. Perform local etching test to determine presence of cracks in propeller blades	1	--	--	2	--
14. Assemble quick engine change units and replace power plants in accordance with current directives	1	2	1	--	--
15. Determine cause of aircraft power plant malfunctions by approved trouble-shooting procedures	1	1	1	--	--
16. Inspect work accomplished to insure safe and proper installation and performance	C	C	C	C	C
103 ADMINISTRATIVE AND/OR CLERICAL					
1. Use NavAer Publications Index to locate, identify, and obtain technical publications	3	3	3	3	3
2. Make required entries in aircraft, power plant, propeller, and accessory records and/or log books	3	3	3	3	3

Qualifications for Advancement in Rating	Applicable Rates				
	AD	ADE	ADF	ADP	ADG
100 PRACTICAL FACTORS—Continued					
103 ADMINISTRATIVE AND/OR CLERICAL—Con.					
3. Use aeronautical technical publications including operating handbooks, preservation handbook, erection and maintenance manuals, allowance lists, service instructions, parts catalogs, aviation circular letters, Technical Notes, Technical Orders, changes, and bulletins pertinent to maintenance of aircraft power plants, propellers, and accessories	2	2	2	2	2
4. Determine part and stock numbers from available technical supply publications for obtaining replacement materials	2	2	2	2	2
5. Conduct on-the-job training and supervise personnel engaged in maintenance, service, and operation of:					
a. Power plants and accessories	1	1	1	--	--
b. Propellers and accessories	1	--	--	1	--
c. Fuel and water injection systems	1	--	--	--	1
6. Conduct classroom instruction within own activity for the training of personnel engaged in maintenance, servicing, and operation of aircraft power plants, propellers, accessories, and fuel and water injection systems	1	1	1	1	1
7. Organize and supervise classroom instruction and on-the-job training for personnel engaged in maintenance, servicing, and operation of aircraft power plants, propellers, accessories, and fuel and water injection systems	C	C	C	C	C
8. Organize work assignments and supervise personnel to accomplish maintenance projects as directed	C	C	C	C	C
9. Organize and maintain a technical library of aeronautical publications required by applicable allowance list	C	C	C	C	C

Qualifications for Advancement in Rating	AD	ADE	ADF	ADP	ADG
200 EXAMINATION SUBJECTS					
201 OPERATIONAL					
1. Safety precautions and emergency procedures pertaining to maintenance, servicing, and inspection of aircraft and during power plant run-ups	3	3	3	3	3
2. Prescribed methods of aircraft inspection and servicing, including ground operation of power plants and auxiliary power units	3	3	3	3	3
3. Functional use of power plant instruments in relation to power plant operation	3	3	3	3	3
4. Types and designations of aviation fuels; octane ratings and their effects on engine performance	3	3	3	3	3
5. Procedures for operating aircraft power plants and auxiliary power units before, during, and after flight, including taxiing, take-off, climb, cruise, and landing	2	1	2	--	--
6. Principles of weight and balance control as applied to loading of aircraft in preparation for flight	2	1	2	--	--
7. Procedures for determining basic aircraft weight and location of center of gravity	C	C	C	--	--
202 MAINTENANCE AND/OR REPAIR					
1. Name and use of aircraft maintenance hand tools and measuring instruments	3	3	3	3	3
2. Identify the components of aircraft power plants, propellers, accessories, fuel and water injection systems	3	3	3	3	3
3. Color coding system used in naval aircraft to designate and indicate use of fuel, oil, and water injection lines	3	3	3	3	3
4. Procedures for periodic inspections and checks of:					
a. Power plants and accessories	3	3	3	2	--
b. Propellers and accessories	3	3	3	3	2
c. Fuel and water injection systems	3	3	2	--	3

(Column group heading: *Applicable Rates*)

Qualifications for Advancement in Rating	AD	ADE	ADF	ADP	ADG
200 EXAMINATION SUBJECTS—Con.					
202 MAINTENANCE AND/OR REPAIR—Con.					
5. Operating principles of the following to include subassemblies and their component parts:					
a. Power plants and accessories	2	3	2	--	--
b. Propellers and accessories	2	--	2	3	--
c. Fuel and water injection systems	2	2	2	--	3
6. Required adjustments in maintenance and servicing of:					
a. Power plants and accessories	2	2	1	--	--
b. Propellers and accessories	2	--	--	2	--
c. Fuel and water injection systems	2	2	--	--	3
7. Procedures to be followed in preserving and depreserving aircraft power plants, propellers, accessories, fuel and water injection systems	2	2	--	2	2
8. Causes and symptoms of aircraft power plant malfunctioning and trouble-shooting procedures	1	1	1	--	--
203 ADMINISTRATIVE AND/OR CLERICAL					
1. Type and purpose of records, logs, and reports applicable to servicing, maintaining, operating, receiving, and transferring aircraft, power plants, propellers, and accessories	3	3	3	3	3
2. Types of information contained in aeronautical technical publications, including operating handbooks, erection and maintenance manuals, preservation handbooks, allowances lists, service instructions, parts catalogs, aviation circular letters, Technical Notes, Technical Orders, changes, and bulletins pertinent to aircraft power plants, propellers, and accessories	2	2	2	2	2
3. Organizational methods to be followed for accomplishing line and shop maintenance and inspections	C	C	C	C	C

Applicable Rates: AD, ADE, ADF, ADP, ADG

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